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SOLAR HEAT.

BY CAPTAIN JOHN ERICSSON.

From "Engineering."

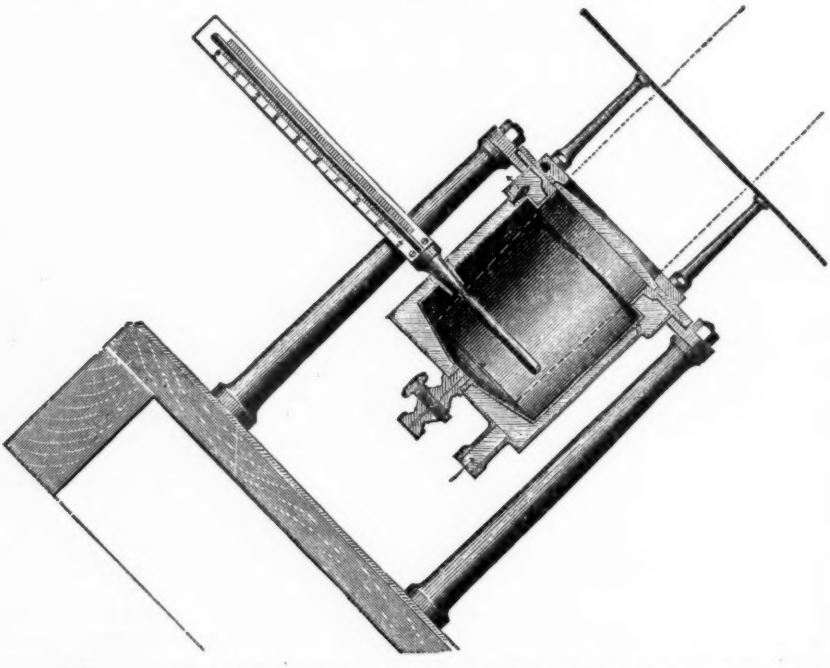
The accompanying illustration represents a longitudinal section of an actinometer which I have constructed for the purpose of ascertaining the intensity of solar radiation near the surface of the earth. It will be evident, on reflection, that experimental researches relating to the sun's radiant heat require that the intensity should be known at every moment, if possible, by mere inspection, since it is continually changing.

During the early part of my investigations I lost much time for want of reliable means of ascertaining the actual intensity of the rays at the moment of observing the effect of the sun's heat on the instruments employed. To be brief, the observed results all conflicted, no two observations tallying, thus involving the whole question in uncertainty and confusion. The causes which affect the intensity of the heat imparted to substances exposed to solar radiation are chiefly the sun's zenith distance, on which depends the depth of atmosphere to be penetrated by the rays; the temperature of surrounding objects, and of the immediately surrounding atmosphere, which radiate heat towards the exposed substance, these temperatures being modified by a variety of circumstances wholly beyond control—clouds and aqueous particles in the air—and possibly the intensity is affected by an irregular evolution of heat in the solar atmosphere. Travellers who have made observations within the tropics state, in order to point out the great intensity of the sun's rays in places where they descend vertically, that, while the temperature in the shade marks 83 deg. it frequently exceeds 150 deg. in the sun, thus indicating an intensity of solar radiation fully 67 deg. The observations of Daniell, frequently referred to in works on Meteorology, conducted in the latitude of Washington, where the depth of the atmosphere at the summer solstice is only 0.038 greater than on the ecliptic, are so instructive that I subjoin his Table on solar radiation throughout a day in the month of June:

Time.	Temperature.		Difference.	Time.	Temperature.		Difference.
	In sun.	In shade.			In sun.	In shade.	
a. m.	deg.	deg.	deg.	p. m.	deg.	deg.	deg.
9.	93	68	25	2.	143	75	68
9 30	103	69	34	2.30	138	76	62
10.	111	70	41	3.	138	76	62
10.30	119	71	48	3.30	132	77	55
11.	124	71	53	4.	124	76	48
11.30	125	72	53	4.30	123	77	46
12.	129	73	56	5.	112	76	36
12.30	132	74	58	5.30	106	75	31
1.	141	74	67	6.	100	73	27
1.30	140	75	65				

A glance at this Table shows that, according to the adopted method of determining the intensity of solar radiation by

deducting the temperature indicated by a thermometer in the shade from the temperature attained in the sun, the radiant heat is less powerful before than after noon. The differential temperature, or solar intensity, at 9 A. M., according to this Table, is 25 deg. while at 3 P. M., with very nearly an equal zenith distance and equal depth of atmosphere to penetrate, the solar intensity is shown to be 62 deg. I will not detain the reader by explaining the causes of the errors of Daniell's Table, my object being simply to point out the gross imperfection of such a mode of determining solar radiation as that of noting the different indications of shaded and



exposed thermometers. During the early stages of my investigation before adverted to, I adopted this method of ascertaining the actual intensity of radiant heat; but, notwithstanding numerous expedients resorted to in order to prevent the thermometers from being unduly influenced by the radiant heat of the air and surrounding objects, I failed to secure satisfactory results. The most important point—the controlling the radiation of the surrounding air, which affects the exposed as well as the shaded thermometer—having presented obstacles which no mechanical arrangement whatever could overcome, I have adopted the expedient of wholly excluding the atmosphere. By this means the bulb of my actinometer is surrounded by the ether alone, the molecular motion of the solar ray being thus permitted to regulate the temperature, free from atmospheric influence. It will be objected that the bulb of the thermometer cannot be applied within a vacuum without the employment of some transparent covering, and that, consequently, the energy of the rays will suffer considerable loss before reaching the instrument. To meet this objection I apply a thin lens of 40 in. focus, inserted at such a distance from the bulb that the gain by concentration will exactly balance the loss of calorific energy attending the passage of the rays through the crystal.

A close inspection of the accompanying illustration, together with the foregoing statement relative to the object and nature of the lens, and the applying the

thermometer within a vacuum, render a minute description of the actinometer superfluous. This instrument, like the solar calorimeter, is attached to a table, the face of which is kept perpendicular to the sun during observations; provided likewise with mechanism by means of which the sun's zenith distance may be ascertained at every instant. The chamber containing the bulb of the thermometer is $4\frac{3}{4}$ in. in diameter, plated with polished silver, and surrounded with a double casing, through which a current of water is circulated by means precisely like those employed in the solar calorimeter, the vacuum being also produced in a similar manner, and flexible pipes employed for connecting the instrument with the stationary pumps, to admit of the necessary compound movement of the table. The cistern which supplies the circulating water is kept at a constant temperature of 60 deg. and in order to secure perfect accuracy, the thermometer employed for regulating this temperature is so applied that the return current from the actinometer to the cistern circulates round its bulb. A thin metallic screen of annular form, supported by four columns, and plated with silver, protects the instrument from the sun's radiant heat, for the purpose of economizing the cooling medium required to keep the circulating water at the proper temperature. The opening in the screen corresponds with the size of the lens. The bulb of the thermometer is three in. in length, in order to expose the greatest possible surface compared with its contents. The upper half of the bulb is coated with lampblack, the lower half being exposed to the action of the reflected rays from the bottom of the chamber, in such a manner that the radiation of this lower bright half of the bulb is neutralized by reflected heat.

Before turning the instrument to the sun, the vacuum gauge should be inspected, and the water from the cistern should be permitted to run freely through the casing for several minutes until the temperature of the return current and that indicated by the actinometer correspond. The table being then turned to the sun, the expansion of the contents of the elongated bulb will in a few minutes indicate with absolute certainty the intensity of the sun's radiant heat, independent of atmospheric temperature and the multitude of disturbing causes which render the indications of solar intensity by common thermometers mere approximations. In view of the foregoing explanations, it is hardly necessary to state that the zero of the thermometric scale of the actinometer is 60 deg. above Fahrenheit's zero, and that whatever point is reached by the mercurial column of the actinometer above its zero, after turning the lens toward the sun, can only be attained in virtue of the power of unaided solar radiation. It will be well to bear in mind that the bulb is surrounded by ether alone, freed from all disturbing influences of gaseous matter, and that the heat which determines the zero of the actinometer is supplied by radiation from the instrument itself. The necessary illustrations not having been yet presented, the question of actual intensity cannot now be entertained. It will, nevertheless, be proper to observe, that the actinometer merely shows the thermometric interval of solar intensity on Fahrenheit's scale, without reference to the position of that interval on a scale which commences at the accepted "absolute zero." I regard this absolute zero, however, as an *ignis fatuus*, retreating as fast as we approach it. In support of this, it will be proper to mention that the law of decrease of temperature in the inverse ratio of the square of the distances, together with my actinometer observations, which determine the actual diminution of solar intensity for the increase of 0.0334 of the distance between the sun and the earth, during the summer solstice, warrant the assertion that solar intensity on the surface of Neptune is far below our assumed absolute zero. Neptune receives light from the sun; can there be a doubt that this planet also receives *heat*, although of an intensity below absolute zero?

It only remains to be stated that my observations with the actinometer have been made in lat. 40 deg. 42 min., thus only 17 deg. 12 min. from the tropic of Cancer. The depth of atmosphere so near the tropics being, at midsummer, only 0.047 greater than on the ecliptic, while the sun's zenith distance on lat. 40 deg. 42 min. during the winter solstice is only 2 deg. 18 min. less than at the pole at midsummer, I have been enabled to determine the maximum

intensity of solar radiation for all latitudes from the equator to the pole. Fig.

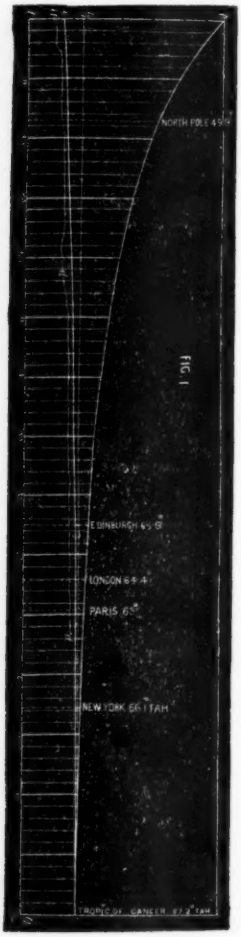


FIG. 1

1 is a diagram presenting the relations of atmospheric depth and solar intensity for each degree of zenith distance to the 75th degree. A brief description will suffice to render this diagram easily comprehended. The ordinates between the curve *e a* and the base line, *f g*, exhibit the true proportions of the depth of the atmosphere from the vertical to 75 deg. zenith distance; while the ordinates of the curve, *c a*, indicate the relative intensity of the sun's radiant heat at the summer solstice, for each degree of the sun's zenith distance from the vertical to 75 deg. The straight line, *b a*, is the tangent of the curves, *e a* and *c a*. It will be seen by closely examining these curves, and the ordinates resting on the base line, *f g* (comparing the same with the figures in the accompanying Table), that the intensities of solar radiation vary in the inverse ratio of the cube roots of the atmospheric depth. The ordinates between the irregular line, *d d d*, and the base line, *f g*, show the solar intensity for each degree of zenith distance from 23 deg. to 75 deg., ascertained by actinometer observation 5th of August, 1870. With reference to the solar engine this irregular line, *d d d*, possesses great interest, as it indicates the available solar energy, for mechanical purposes, during a day when the sun is obscured with *cirri* of unusual density.

The engineer will regard this diagram as a solar indicator card, the space below the line, *d d d*, representing the available power, while the space contained between that line and the curve, *c a*, indicates the loss. For the purpose of elucidation, the North Pole, together with the cities of Edinburgh, London, Paris, and New York, have been introduced on this diagram, their positions having reference solely to the depth of atmosphere and solar intensity during the summer solstice. The accompanying Table shows the depth of atmosphere and maximum solar intensity at midsummer for each degree of the sun's zenith distance from the vertical to 75 deg. (See page 566.)

The observed solar intensity for each degree of zenith distance from 23 deg. to 75 deg. August 5th, 1870, has been introduced into this Table, as before stated, to enable us to determine what amount of radiant heat is lost when the sun's rays are obstructed by *cirri* of considerable density.

Fig. 2 represents a graduated plate furnished with a movable radial index, to enable the observer to ascertain quickly the depth of atmosphere corresponding with observed zenith distances. The graduated plate is constructed to a scale of 14 miles to the inch, the curvature of the earth's surface and the atmospheric boundary 42 miles above the earth being accurately laid down agreeable to the scale mentioned. It will be seen that the vertical depth of the atmosphere has been di-

vided into 100 equal parts, and that the same graduation has been introduced on the movable index. Accordingly, by placing the index at angles corresponding

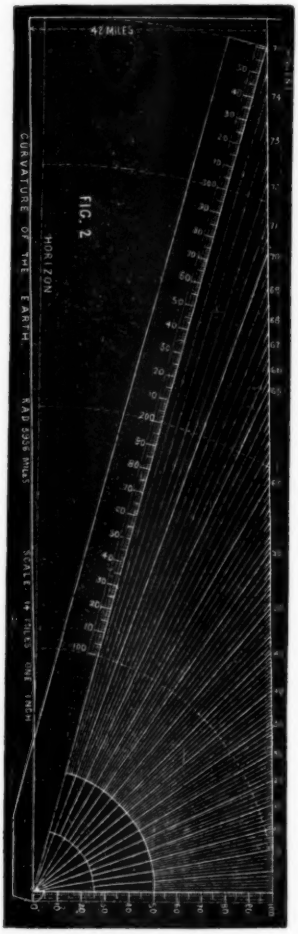


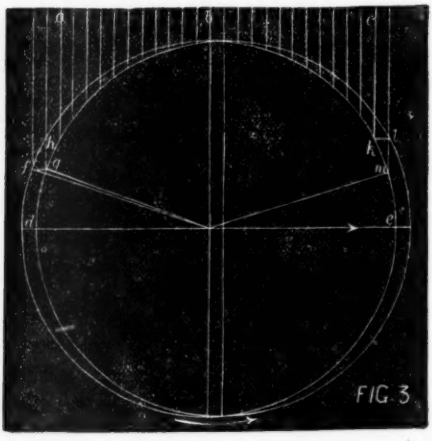
FIG. 2.

with the observed zenith distances, the intersection of the top line of the atmosphere with the edge of the index will show the relative diagonal and vertical depth.

As far as ascertained by means of the actinometer, there is an appreciable difference in the sun's energy for corresponding zenith distances early in the morning and late in the afternoon, which cannot be traced to any adequate physical cause. I have accordingly attempted to explain the discrepancy on the ground that the orbital motion of the earth occasions a very considerable advance towards, and retreat from, the solar wave early A. M., and late P. M. The subject will be readily understood by reference to Fig 3, which represents a section of the earth through the plane of the ecliptic, the line *d e* indicating the orbit, and the straight arrow the earth's course; while the curved arrow shows the direction of rotation; *a b c*, etc., represent the sun's rays; the orbital velocity during a definite period being represented by *f g* and *k l*. Let us assume that the latitude of the point *f*, on the earth's surface, is such that the prolongation of the ray *a h* to *g*, makes *h g* three times longer than *f g*. It will now be evident that the ray *a h*, which has been arrested at *h*, must, while the earth advances from *f* to *g*, continue its course at a rate three times greater than the earth's orbital velocity, in order to reach *g* simultaneously with *f*. Assuming the mean distance of the earth from the sun to be 91,430,000 miles, the orbital velocity will be 96,120 ft. per second; hence the ray *a h*, to keep up with the retreating western quarter of the globe, must move at the rate of 288,360 ft. per second. The advancing eastern quarter obviously imparts a retrograde movement to the solar wave, consequently the ray *m l* will, on grounds already set forth, be pushed towards the sun at the rate of 288,360 ft. per second. We have thus established a difference of advancing and retreating velocity exceeding 600,000 ft. per second, for the lower altitudes, which unquestionably interferes with the regularity of the solar wave, and thereby tends to disturb the uniformity of the intensity of the sun's radiant heat towards evening. Meteorologists will account for the observed diminution by pointing to the fact that during sunshine —without which the actinometer cannot be used—the atmosphere, in most localities, gradually becomes charged with vapor as the day advances; and that dust and other light dry particles are carried up into the atmosphere by the ascending heated current of air, thus obstructing the sun's rays. These plausible reasons lose their force if we consider that during the season most favorable for actinometer observations, the vapors are held fast

within icy boundaries, and that the dust is buried under the snow.

The extraordinary velocity of light, nearly 1700 times greater than the velocity shown by the foregoing demonstration, will be urged as a reason why the disturb-



ance of the solar wave could not be practically appreciable. I cannot accept this objection as conclusive unless it can be shown that the dynamic energy imparted by solar heat is not partially the result of arresting the motion of the rays. The following facts connected with the subject, demand serious consideration. Owing to the orbital motion of the earth, the lens of the calorimeter, while exposed to the radiant heat, sweeps across the path of the sun's rays at the rate of 96,120 ft.

Zenith distance.	Depth of atmosphere.	Maximum intensity.	Observed intensity, Aug. 5, 1870.	Zenith distance.	Depth of atmosphere.	Maximum intensity.	Observed intensity, Aug. 5, 1870.	Zenith distance.	Depth of atmosphere.	Maximum intensity.	Observed intensity, Aug. 5, 1870.
deg.		Fahr.	Fahr.	deg.		Fahr.	Fahr.	deg.		Fahr.	Fahr.
Vertical.	100.	67 20									
1	100.	67.20	....	26	111.1	64.86	58.4	51	157.7	57.72	50 7
2	100.	67.19	....	27	112.1	64.67	57.5	52	161 2	57 31	50.6
3	100.1	67 18	....	28	113.2	64.48	57 7	53	164.8	56.89	45.8
4	100 2	67 16	....	29	114·1	64.28	57.7	54	168 6	56.46	45.4
5	100 3	67 12	....	30	115 2	64.07	57.8	55	172 6	56 02	45 6
6	100.5	67 08	....	31	116 4	63 85	56 9	56	176 9	55 56	44.6
7	100.7	67.02	....	32	117 6	63.63	56.9	57	181.5	55 09	47.0
8	101 0	66 96	....	33	118 9	63.40	56.7	58	186.4	54.60	48 0
9	101.3	66 90	....	34	120.3	63.16	57 0	59	191 6	54 10	47 3
10	101 6	66.84	....	35	121.7	62.92	56.8	60	179.0	53 58	47.4
11	101 9	66.77	....	36	123 2	62 67	56.4	61	203 7	53.05	46 4
12	102.3	66 70	....	37	124 8	62 40	56 2	62	209 8	52.50	46 8
13	102 7	66.62	....	38	126 5	62 11	55.8	63	216.4	51.90	46.8
14	103.1	66 54	....	39	128.3	61.81	56.1	64	223 5	51.40	46 4
15	103.6	66.44	....	40	130.2	61.50	55.0	65	231.2	50.81	46.1
16	104 1	66 33	....	41	132.2	61.19	54 8	66	239.8	50.20	45.0
17	104 6	66.21	....	42	134.2	65.88	54.8	67	249 0	49.57	42 6
18	105.1	66 08	....	43	136.3	65.57	54.9	68	259.1	48 91	43.1
19	105.7	65 95	....	44	138.4	60 25	54.6	69	270.1	48.25	43.2
20	106.3	65.82	....	45	140.6	59 93	54.7	70	282 1	47.55	42 8
21	107 0	65.68	....	46	143.1	59 60	54 5	71	295.2	46.84	41.9
22	107.7	65.53	....	47	145.7	59.25	54.4	72	309.7	46.12	40.4
23	108.5	65.38	59.5	48	148.5	58 88	53.4	73	325.5	45.37	33 5
24	109 3	65.22	58 4	49	151 4	58.51	53 0	74	342.8	44.60	36.3
25	110.2	65.04	57.7	50	154.5	58 12	53.2	75	362.4	43 78	32.4

per second; hence the fluid contained within receives the dynamic energy resulting from the extinguished *vis viva* and molecular motion of a countless number of rays following each other in an inconceivably rapid succession.

Pouillet having ascertained the number of units of heat imparted to the water in his pyrheliometer of one decimetre (3.93 in.) diameter, imagined that he had measured the force of a sunbeam of 11.9 square inches section; whereas, in reality, he had at the end of his experiment of five minutes' duration, accumulated a force generated by extinguishing the *vis viva*, and receiving successively the molecular motion of the entire number of rays contained in a passing sunbeam, the section of which may be ascertained by multiplying the orbital advance of the earth during five minutes—28,836,000 ft.—by the diameter of the pyrheliometer, 3.93 in.= 9,443,790 square feet.

NEW YORK, *September* 6, 1870.

DETERMINATION OF THE UNIT OF OBLIQUE PRESSURE.

BY C. LE BLANC.

Translation from "Annales du Port Chausèes."

If the resultant P of a pressure makes an angle a with the normal to the resisting plane, the usual method employed to find the pressure upon a unit of surface is by resolving normal and parallel to the plane; the parallel component is neglected, and the normal taken into account.

The writer has shown, in an article on oblique arches published in the "Annales des Ponts et Chausées" in 1856, that this method is wrong; and that the plane is subjected to normal pressures whose resultant is a force of which the orthogonal projection is is the oblique resultant of the pressures, equivalent to

$$\frac{P}{\cos a}.$$

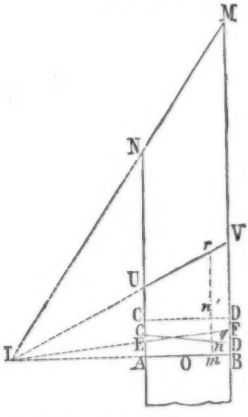
This view seems to have met slight recognition, the usual method having been employed in many articles since published in that periodical. Yet this method may mislead to insecure construction; for, as the friction angle of masonry is generally greater than 30°, a structure may be considered secure, in which the resultant of the pressures upon a joint includes an angle of 30° with the normal. In this case the pressure upon a square centimeter found by the old method is less than the real pressure in the ratio of the quotient (cos 30°), *i.e*, about 30 per cent; viz.—6 kilog., instead of 8 kilog.

The object of this paper is to show that the old method is erroneous.

Preliminary Considerations.

If a solid body in the form of a right prism with an end-surface F is fixed to a supporting plane, with its axis horizontal, and subjected to a uniformly distributed pressure upon one end whose resultant R is parallel to the axis, the operation of weight in the direction of the axis is null, if the original height was H, and it is reduced by pressure to H, the regular diminution of length, $\frac{H - H'}{H}$, until the limit of elasticity is reached is in a constant ratio to the unit pressure $\frac{R}{F}$, so that

FIG. 1.



$$\frac{R}{F} = E. \frac{H - H'}{H}$$

E being the modulus of elasticity. In this case upon removal of pressure the body is restored to its origiinal length, which is not the case if the limit of elasticity has

passed. For a tensile load Rt, the same holds true, so that

$$\frac{Rt}{F} = E' \frac{H' - H}{H}. \qquad (1)$$

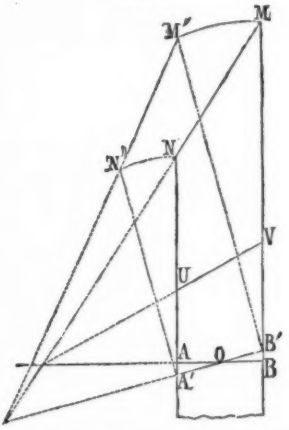
If the tensile or compressive forces are not constant along the length of the prism, but vary continuously, the prism may be considered as divided into horizontal laminæ of infinitesimal thickness, and the above equations apply to each of these.

In all calculations of resistance the dimensions of the several parts of a structure must be determined so that the molecular variations in length may not exceed certain limits of elasticity; and this may be done by finding the direction in which the alteration in length is a maximum and applying the above equation. This equation expresses the fundamental law of all construction; it is therefore important that it should be understood, and it should not be forgotten that this equation holds only on the hypothesis that the section F has a normal position to the force R. But it often happens that the unit pressure for a section oblique to the resultant strain has to be determined. If the usual process is followed in which only the normal component of the resultant is sought for, the above equation gives the contraction normal to the section, but not the maximum contraction, which takes place in the direction of the resultant. The decomposition into normal and tangential components only serves to determine whether sliding will take place in the sectional plane. If the friction prevents this, cohesion has unhindered action, and the strains in the section must be otherwise considered.

Rectangular sections and position of the resultant in a plane symmetrical to the section plane.

Suppose a vertical prismatic column of homogeneous masonry of sectional area, F, limited by an oblique section M N, which is normal to two parallel faces of the prism; let us determine what is the relation to the limits of elasticity of a point within the column at a distance H′ from the upper edge of the section. We consider the effect of gravity upon an element between two sections, one passing through the point O, the other at the infinitesimal distance η. This element is made shorter by the pressure of the part of the column above, but not uniformly, since the effect is not uniformly distributed. Both limiting planes have suffered deformation; but it can be assured, according to Navier's hypothesis, that the surfaces have remained plane. It follows from the symmetric position of the normal plane with respect to the oblique plane which passes through the axis of the column, that both limiting planes remain normal to the plane of symmetry; hence the relative shortening $\frac{\eta - \eta'}{\eta}$ is constant through the whole horizontal extent of the cutting plane O. It is therefore only necessary to find the law of contraction in the trace of the cutting plane O with the plane of symmetry, and to consider the point O as a point of this trace.

Fig. 2.



In Fig. 2, let A B be the trace of the cutting plane O, with the plane of symmetry, C D that of the second bounding plane of the element, A N and B M those of the prism faces normal to the plane of symmetry, C′, D′ the trace of the original second limiting plane of the element before compression by gravity. The distance $m'\ n'$ between A B and C′ D′ is η, that between A B and C D η'; and $\frac{n\ n'}{m\ n} = \frac{\eta - \eta'}{\eta}$.

In the trapezium A E F B, which is formed, if A E = C C′, B F = D D′, $m\ q = \mu\ \eta' = \mu - \mu'$, and is proportional to the relative contraction of the element. The ordinates of the line E F represent

the corresponding contractions of the several points in the line A B.

If L is the length of the section,
e, its resistance,
l, the distance of a point from A B,
p, the unit pressure upon this point in the direction of the greatest contraction, the pressure upon the element $e\,d\,l$ is $p\,e\,d\,l$, and we have

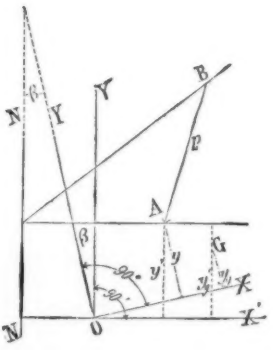
$$\frac{p\,e\,d\,l}{e\,d\,l} = p = \mathrm{E}\,\frac{\eta - \eta'}{\eta}$$

Putting

$$m\,r = m\,q\,\frac{\mathrm{E}}{\eta} = \frac{\mathrm{E}}{\eta}(\eta - \eta') = p,$$

and drawing from r a straight line to the intersection F of the lines A B and E F, the ordinates of the line U V are proportional to those of the line E F, and are numerically equal to p. We have then but to determine the line U V in order to find the unit pressure in the direction of greatest compression of every point of the line A B. The determination is easily made as follows :

Fig. 3.



In Fig. 3 let A N M B be a vertical section of the column along the plane of symmetry O ; A B, U V have the same reference as in Fig. 2 ; R be the weight of the upper portion of the column, or the resultant of the pressures upon the plane O ; we then have

$$\int_0^l p\,e\,d\,l = \mathrm{R}.$$

If the distance of the resultant R from A B is represented by G.

$$\int_0^l p\,e\,(l_1 - l)\,d\,l = \mathrm{R\,G}.$$

If p is the ordinate of the side U V of the trapezium, and s the surface of this trapezium, g being the distance of its centre of gravity from M B, we have

$$\int_0^l p\,e\,d\,l = e\int_0^{l_1} p\,d\,l = e\,s$$

and

$$\int_0^l p\,e\,(l_1 - l)\,a\,l = e\int_0^l p\,(l_1 - l)\,d\,l = e\,s\,g$$

$$e\,s = \mathrm{R} \text{ and } e\,s\,g = \mathrm{R\,G}, \text{ or}$$

$$(2)\ s = \frac{\mathrm{R}}{e} \text{ and } (3)\ g = \mathrm{G};$$

consequently, the surface of the trapezium is equal to the weight of the portion of the column above the section O, for the unit of resistance, and the resultant passes through the centre of gravity of the trapezium.

Both relations (2) and (3) express the line U V as a function of R and G, and as these magnitudes are easy to determine, the solution of the above follows of course. We now confine ourselves to the expression of the contraction at the point O, and the unit pressure in the direction of the greatest contraction as a function of G and R. If, in Fig. 3, $h = \mathrm{B\,V}$, and $h_2 = \mathrm{A\,U}$, we have

$$s = \frac{h_1 + h_2}{2}\,l_1, \text{ and from (2)}$$

$$\frac{h_1 + h_2}{2}\,l_1 = \frac{\mathrm{R}}{e}, \text{ or } \frac{h_1 + h_2}{2} = \frac{\mathrm{R}}{e\,l_1}$$

consequently it appears that, independent of G and of the point of application of the resultant R, the unit pressure in the axis of the column is as great as if the resultant R were uniformly distributed.

Again, if h is the ordinate of a point in U V, and l its distance from the line A B, we have

$$h = h_2 + \frac{h_1 - h_2}{l_2}\,l. \quad . \ . \ . \quad (5)$$

therefore

$$s\,g = \frac{h_1 + h_2}{2}\,l_1\,g = \int_0^{l_1}\left(h_2 + \frac{h_1 - h_2}{l_1}\,l\right)(l_1 - l)\,d\,l$$

and

$$g = \frac{h_1 + h_2}{3\,(h_1 + h_2)}\,l_1 \quad . \ . \ . \quad (6)$$

and from (3)

$$\mathrm{G} = \frac{h_1 + 2\,h_2}{3\,(h_1 + h_2)}\,l_1$$

from (4) and (7)

$$h_1 = \frac{\mathrm{R}}{l_1\,e}\cdot\frac{2}{\ldots}\,(2\,l_1 - 3\,\mathrm{G}),$$

$$\frac{\mathrm{R}}{l_1\,e}\cdot\frac{2}{l_2}\,(3\,\mathrm{G} - \ldots),$$

substituting in (5)

$$h = \frac{R}{l_1 e} \cdot \frac{2}{l_1} [l_1(3G - l_1 + 3\lambda(l_1 - 2G)]$$

or

$$h = \frac{R}{F} \cdot \frac{2}{l_1} l_1(3G - l_1 + 3\lambda(l_1 - 2G)], \quad (8)$$

if λ stands for the value of l at the point O.

Again in Fig 1 let B m=H, A n =H_2; we have by (6) and (3) from the trapeziums ABUV and ABNU

$$\frac{H_1 + 2H_2}{3(H_1 + H_2)} l_1 = \frac{h_1 + 2h_2}{3(h_1 + h_2)} l_1$$

or

$$\frac{H_2}{H_1 + H_2} = \frac{h_2}{h_1 + h_2}$$

$$\frac{H_1 + H_2}{H_2} = \frac{h_1 + h_2}{h_2} \text{ or } \frac{H_1}{H_2} = \frac{h_1}{h_2},$$

Hence the lines U V and N M intersect at the same point in the line AB; and if that part of a vertical between AB and NM be indicated by H and the corresponding pressure in this vertical by h, we can put h=KH, K being a numerical constant. We then have

$$\int_0^{l_1} h e dl = \int_0^{l_1} \pi H e dl$$

or

$$Ke \int_0^{l_1} H dl = \pi e \int_0^{l_1} dl$$

$\therefore K = \pi$ and $H = \pi H$.

It follows that the Navierian hypothesis for the normal section of the column cannot be correct, if it does not hold for any section. This may be proved generally; but it is sufficient here to do so for an oblique section normal to the plane of symmetry.

Such a plane cuts the plane of symmetry obliquely if the column is not under the action of gravity. To determine what position any point of this oblique section would take under the influence of gravity, we consider this point as belonging to the right section in which it is situated. We see that it has descended $\eta = \eta_2$; but this is proportional to p or h, and since $h = \pi H$, $\eta - \eta$ is proportional to H, or the depth of the given point below the end surface; hence the geometric locus of the point is a straight line.

We have now to obtain the unit pressure at O in the direction of the maximum pressure. This must lead to the same value of p or h, as equation (8); for the pressure is independent of the section by means of which it is found. Our new method of calculation indeed leads to the same value.

In Fig. 3 let A′B′ be the oblique section, Q the angle of this plane with the right section AB, R′ the resultant of gravity upon A′B′NM. According to the new method we have to substitute for the oblique resultant R′ the pressure $\frac{R'}{\text{Cos } a}$ normal to the section, which is to be considered as the resultant of the elementary pressures normal to A′B′ in a distribution according to Navier's hypothesis. The weight of a column A′B′N″M″ normal to A′B′, in which the action of gravity becomes parallel to the edges of the column, fulfils these conditions, provided that the direction of the weight of A′B′N″M″ (parallel to B M) pierces the plane A′B′ in the same point in which the direction of the weight of A′B′NM (parallel to B M) pierces it.

Let L″ be the length of A′ B′,
F″ its area,
λ″ the distance of O from the line A′ N″,
G″ the distance of the point of application of R′,
s, l, and λ, meaning as before;

We obtain by (5) for the unit pressure h' of the section A′ B′, bearing the column A′ B′ N″ M″.

$$h' = \frac{R' \cdot \frac{1}{\cos a}}{F''} \frac{2}{l_1''^2} [l_1''(3G'' - l_1'') + 3\lambda''(l_1'' - 2G'')]$$

and since

$$F'' = \frac{F}{\cos a'}, \; l_1'' = \frac{l_1''}{\cos a}, \; \lambda'' = \frac{\lambda}{\cos a'},$$

$$G'' = \frac{G'}{\cos a}, \text{ we have}$$

$$h' = \frac{R'}{F} \cdot \frac{2}{l_1^2} [l_1(3G - l_1) + 3\lambda(l_1 - 2G')]. \quad (9)$$

On the other hand, if we regard O as belonging to right section A B, (8) gives

$$h = \frac{R}{F} \cdot \frac{2}{l_1^2} [l_1(3G - l_1) + 3\lambda(l_1 - 2G)].$$

To show the equality of h and h', we must express R, G, R′, and G′ as functions of the same magnitudes. In Fig. 3 let B M = H, A N = H_2, B′ M = H'_1, A′ N = H'_2, and π = the weight of the unit volume of the column; then

$$R = \pi F \frac{H_1 + H_2}{2} \text{ and } R' = \pi F \frac{H_1 + H_2}{2},$$

Again (6) applied to A B N M and A′ B′ N M gives

$$G = \frac{H_1 + 2H_2}{3(H_1 + H_2)} l_1 \text{ and } G' = \frac{H_1' + 2H_2'}{3(H_1' + H_2')} l_1,$$

by substitution, from

$$(8)\quad h = \pi \frac{1}{l_1} [l_1 H_2 + \lambda (H_1 - H_2)]$$

from

$$(9)\quad h' = \pi \frac{1}{l_1} [l_1 H_2' + \lambda (H_1' - H_2')].$$

But

$$H_1' = H_1 - B B' = H_1 - O B \, tg\, a = H_1 - (l_1 - \lambda) tg\, a,$$
$$H_2' = H_2 + \lambda \, tg\, a,$$

hence from (9)

$$h' = \pi \frac{1}{l_1} [l_1 (H_2 + \lambda \, tg\, a) + \lambda (H_1 - (l_1 - \lambda) \, tg\, a - H_2 - \lambda \, tg\, a)]$$
$$= \pi \frac{1}{l_1} [l_1 H_2 + l_1 \lambda \, tg\, a + \lambda H_1 - l_1 \lambda \, tg\, a + \lambda^2 tg\, a - H_2 \lambda - \lambda_2 \, tg\, a]$$
$$= \pi \frac{1}{l_1} [l_1 H_2 + \lambda (H_1 - H_2)] = h.$$

The new method then, in its application to an oblique section normal to the plane of symmetry of a rectangular column of masonry, whose upper surface is oblique, but normal to two parallel faces, obtains an exact expression for the unit pressure in the direction of the greatest compression. This method in general gives correct results for each rectangular section, so long as the resultant of the pressures lies in a plane of symmetry to the section, and the Navierian hypothesis is admissible. For example, let us take a joint of an arch, to which the resultant of pressures, according to Mery's theory, is oblique. That part of the arch which lies between the crown and the joint, and the masonry above, have caused the pressures to which the resultant is due. These pressures are themselves determinate functions of the magnitude and direction of the resultant, as well as of the point of application. For, by Navier's hypothesis and by equation (1), it follows that the greatest contraction at every point of the joint, and the element pressure caused by it, are proportional to the distance, measured parallel to the resultant, between the point and a joint at an infinitesimal distance. Parallel forces acting upon given points of a plane are fully determined, if their resultant is known in magnitude and direction.

If this is given, we consider parallels to the resultant of the pressures as drawn through each edge of the given joint, and regard these as the edges of a column of masonry, in which gravity acts parallel to the edges; then cut it off by an oblique plane parallel to the plane of symmetry, and assume that the given sectional plane is subjected to the pressure due to the weight of the column. Putting H_1 and H_2 for the greatest and least edges, q for the current unit weight, the weight of the column is $\frac{H_1 + H_2}{2} q$. If l_1 is the orthogonal projection of the sectional length upon the rectangular section of the column, the distance of the centre of gravity of the column from the face whose height is H_1 is found by (6) to be

$$\frac{H_1 + 2H_2}{3(H_1 + H_2)} l_1$$

and if R is the resultant of the pressures to which the joint is subjected, and G its distance from the face whose attitude is H_1 we have

$$R = \frac{H_1 + H_2}{2} q \quad . \quad . \quad . \quad (10)$$

and

$$G = \frac{H_1 + 2H_2}{3(H_1 + H_2)} l_1 \quad . \quad . \quad . \quad (11)$$

and from these equations the unknown quantities H_1 and H_2 can be found. Hence, in general there is a column with the determined altitudes H_1 and H_2, which by its weight would exert upon the given joint a pressure whose resultant would be just as great as that of the pressures to which the arch is actually subjected.

The Navierian hypothesis is also applicable to the joint if it is considered as belonging to the column. Consequently, the elementary pressures upon the joint are expressed as functions of the magnitude and direction of the resultant and of the position of the point of application. The point of application of the elementary pressures in the joint is the same in the arch as in the column; the resultant is also the same; consequently the elementary pressures must be equal. Hence, it follows that the pressure in the arch joint can be determined upon the hypothesis that it is caused by the weight of the column, and that the results obtained from the consideration of the pressures in a section of a column of masonry are applicable to the arch joint.

Hence, if we wish to calculate the unit pressure at any point in a rectangular section of masonry by a force not normal

to this section, but lying in a plane bisecting two parallel sides of the sectional plane, and normal to it, we put instead of this force, the normal force whose orthogonal projection is equal to it, and proceed as if this force were normal to the cutting plane.

From equations (10) and (11)

$$H_1 = \frac{2R}{q\,l_1}(2l_1 - 3G) \text{ and } H_2 = \frac{2R}{q\,l_1}(3G - l_1)$$

and as H_1 or H_2 may either be negative, and since

$$2l - 3G > 0 \text{ or } G < {}^2/_3\, l_1,$$
$$3G - l_1 > 0 \text{ or } G < {}^1/_3\, l_1$$

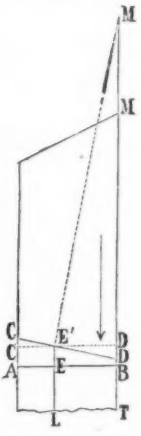
they lie between $\frac{1}{3} l_1$ and $\frac{2}{3} l_1$.

In Fig. 1, the resultant of weight which passes through the centre of gravity of A B N M, cannot be distant from the longer of the two sides H_1 and H_2 less than $\frac{1}{3} l_1$ or more than $\frac{2}{3} l_1$; if one side is 0 the distance is $\frac{1}{3} l_1$. But the column may be subject to external vertical pressures upon its upper surface, which, combined with the weight above, A B, give a resultant R distant less than $\frac{1}{3} l_1$ from B M. If the external forces are of such a nature as to admit Navier's hypothesis, the section C D, which is under action of external forces and of gravity at the infinitesimal distance A C'=B C' from A B, will cut the latter in a straight line whose trace is E'. For if D were entirely below C' D' the resultant of the molecular reactions would pass through the centre of gravity of the trapezium lying between the lines, and therefore would not have an opposite direction to the resultant of the weight of the column and the external forces, which lies at a distance less than $\frac{1}{3} l'$ from B M; while there is always equilibrium if C D cuts the line C' D', provided the limits of elasticity are not passed.

If the material can equally well resist compression or tension, the resultant of the tensile forces would be proportional to the triangle C E' C'; that of the forces of compression, to the triangle D E' D'. Since they maintain the equilibrium of the resultant R, and must pass through the centre of gravity of these triangles, their magnitude is easily determined, as well as the equations necessary to determine the line C D; that is, the amount of compression or extension at any point of the line A B. If it is assumed (a safer hypothesis if pressure is to act upon damp mortar) that the material has only to resist compression, the triangle C E' C' would represent only a parting of the same kind as happens at the foot of an arch upon the sudden displacement above. The triangle, D E' D' represents the molecular action of contraction while its surface is proportional to R and its centre of gravity lies in the direction of R. An obliquely-cut column may also be conceived whose upper portion exerts a weight equal to R on A B.

The part of the section A B, of which the trace is A E, experiences no pressure; the part E B is under the same relations as if it belonged to the column L T E M'; hence the contraction at any place can be calculated as in the case of the last column, and the new method may be applied if the resultant is not normal to the section.

FIG. 4.



If G does not lie within the limits before assigned, the pressures in the section may be still considered as under the pressure due to a column, L T E M', Fig. 5, and the calculation may be made by application of the new method. The portion in question lies between that one of the sides standing perpendicular to the plane of symmetry which lies nearest the resultant, and a parallel to it drawn at the distance $\frac{3G}{\cos a}$, which is also the lowest side of the oblique cutting section of the column. The altitude, H_1, which is given by

$$H_1 = \frac{2R}{3G\epsilon\pi},$$

if π is the weight of a unit volume of the column and ϵ the breadth of the section. It is obvious that the column thus determined has its centre of gravity in the direction of the resultant of pressure, and that its weight, P, corresponds to this resultant:

$$P = 3G\epsilon\frac{H_1}{2}\pi = \frac{3G\epsilon\pi}{2}\cdot\frac{2R}{3G\epsilon\pi} = R$$

H_1 in this case is always positive.

It is consequently proved that the new method is applicable under the above conditions. In cases in which G does not lie between $\frac{1}{3}l_1$ and $\frac{2}{3}l_1$ and the section is reduced to $\frac{3G}{\cos\alpha}$ (measured from the side lying nearest the point of application of the resultant), the calculation of the unit pressure in the direction of the maximum contraction is made by means of the resultant R, if this is normal to the section; but if it is oblique, the magnitude $\frac{R}{\cos\alpha}$ must be used.

THE GAUGE FOR "THE RAILWAYS OF THE FUTURE."*

The object of this paper is to show in what manner, and to some extent in what degree, the cost of the construction and maintenance of railways is affected by the gauge on which they are built; and by what means it would be possible at once to increase the dividends of shareholders, and to extend the countless advantages railways afford to all parts of the habitable globe, however thinly peopled or unproductive. It will be in the recollection of many that the question of the proper gauge for railways was once a matter of earnest dispute; and that what was called the "Battle of the Gauges," as between broad and narrow, was fought with desperate vigor and with no decided result. Each party of belligerents retired from the contest with heavy pecuniary loss; but neither would allow that the other had been the victor. The result was that the construction of each gauge was pushed forward by those who were interested in it; and thus it befell that a broad gauge line was carried into the northern districts, from which its subsequent removal was the best proof that it ought never to have been taken there.

Although the controversy to which I have referred was conducted with singular ability, and at a very lavish expenditure of the money of confiding shareholders, it is curious to observe that those concerned in it seem never to have taken into account the relative *economy* of the plans that they respectively advocated. The consideration of this most important element in the question would have thrown upon it a totally new light. But the very word was at that time unknown to the railway world, and the thing which the word signifies has scarcely yet gained its due share of consideration. Had it done so, the present paper would have been unnecessary; for it would have been proved, years ago, that while a narrow gauge is infinitely less costly than a broader one, its capabilities in respect of power and speed are fully equal to the wants of the country. If this had been known, we should not have seen, as at present, large districts deprived of all prospects of railway accommodation; and thousands of shareholders regretting the loss of that return to which their expenditure has fairly entitled them.

Apart from the important question of economy, the carrying capacity of gauges less than 4 ft. 8½ in. has never yet been considered in its true light. It has been hastily assumed that a line of narrower gauge than this would be very limited, both in its carrying power, and also as regards the speed at which trains could be run; and it has been argued that the saving in cost would be too small to render it desirable to make a change. It is not my purpose to advocate such a change in Great Britain, where a 4 ft. 8½ in. gauge is actually established and at work, and where it affords the necessary facilities for the speeds of 60 or 70 miles per hour that are actually run over it; but only to take the conditions of English railway traffic as an illustration of my general arguments. At the same time it must not be forgotten that these conditions could be in some degree modified in

* A Paper read before the British Association at Liverpool.

the direction of economy by the employment of a new and lighter description of rolling stock. It is known and everywhere admitted that the proportion of non-paying to paying weight in passenger trains is as much as 29 to 1, and in goods trains, exclusive of minerals, as much as 7 to 1. This terrible disproportion is partly due to the system of management pursued; but in a far greater degree to the gauge. The dead-weight of trains conveying either passengers or goods is in direct proportion to the gauge on which they run; or, in other words, the proportion of non-paying to paying weight (as far as this is independent of management) is increased exactly as the rails are farther apart, because a ton of materials disposed upon a narrow gauge is stronger as regards its carrying power than the same weight when spread out over a wider basis. In proof of this proposition I need only cite the case of the Festiniog railway, with its gauge of 1 ft. 11½ in. The wagons used upon it for carrying timber weigh only 12 cwt., and they frequently carry a load of over 3½ tons at a speed of 12 miles an hour. In other words, these wagons carry as much as six times their own weight, whilst the best wagons on the ordinary English narrow gauge do not carry as much as twice their own weight.

The good management of the London and Northwestern Railway is so universally admitted, that it will seem almost presumptuous to select this line as an illustration of the faults of the existing system. I have, however, selected it, because its management is such that its shortcomings must be wholly due to its construction; and I shall proceed to show that, if its gauge were 3 ft. instead of 4 ft. 8½ in., its goods traffic could be hauled at half the present cost, with half the present motive power, and in such a way as to reduce the present tonnage over the road by one half, and to remove the necessity for the heavy expense that is now being incurred in the construction of a third line of rails. I am perfectly prepared for the incredulity with which these statements will at first be received; but I shall prove their correctness by figures that cannot err. The writer who originally said that a train weight of thirty tons had to be set in motion for every ton of passengers carried was at first ridiculed for his pains; but after a time, and when people came to inquire into the matter, it was found that his statement was absolutely correct, insomuch that it is now universally received and admitted. In like manner the facts about the goods traffic require only to be investigated; and every one possessed of common sense will find it easy to understand them.

The goods and mineral traffic on the London and Northwestern Railway for a single year amount to about 15,000,000 tons. I will assume that 5,000,000 out of these 15,000,000 tons are minerals, consisting chiefly of coal; and I will deal only with the 10,000,000 tons of goods which are left as the net residue of the year's carrying. It has been proved that the proportion of non-paying to paying weight is about 7 tons to 1 ton; and this would give 70,000,000 tons of rolling weight employed to carry the 10,000,000 tons of paying load. In order to avoid all risk of exaggeration, I will assume the dead weight to be only as 4 tons to 1, which reduces from 70,000,000 to 40,000,000 tons the weight of the wagons employed to carry the 10,000,000 tons of paying load. The whole gross weight hauled by the locomotives will then be 50,000,000 tons, at an average speed of 25 miles an hour.

The earnings for the goods traffic on this line are 6s. 3d. per train mile; which, at an average rate all round of 1½d. per ton per mile, would give about 50 tons as the paying weight, and 255 tons as the gross weight hauled per train mile. Dividing this 255 tons into the 50,000,000 gives 196,089 trains; which, being divided by the 313 working days of a year, give 626 merchandise trains, over all parts of the Northwestern Railway, in the 24 hours.

The Company's balance-sheet shows that each net ton produces about 4s. 8d. (including minerals, but as the net amount earned per train mile in the merchandise and mineral traffic may be taken as averaging nearly the same, this does not vitiate the argument), which, at 1½d. per ton per mile, makes the average distance traversed by each ton to be about 38 miles; so that as each ton of the total weight hauled runs 38 miles, and the entire length of line worked is 1,432 miles, it follows that there must be on an average 37 merchandise trains distributed over the total length. This number, divided into the total number of trains per day of 24

hours, gives an average of over 17 trains per day running on each mile of the line. My object in bringing the figures to this point is to show that, although at first sight the number, 626 trains per day, looks large, yet, when divided over the entire line, it is comparatively small.

Having arrived at this conclusion, we are in a position to see how it would affect the question if the gauge of the line were 3 ft. instead of 4 ft. 8½ in. In the first place, the same or a greater speed could be maintained, say up to 35 or 40 miles an hour. I mention the speed here because I am dealing with goods trains only. Of course when passenger trains are considered, the element of speed tells largely in favor of the broad (*i. e.*, 4 ft. 8½ in.) gauge; but this has been already admitted. My argument is only intended to show what a 3-ft. gauge is capable of accomplishing in the way of duty, up to a speed of 40 miles an hour; a speed which on such a gauge can only be obtained by the employment of the double bogie engines.

The speeds in each case being therefore equal, the next point to examine is the result of carrying on the narrow gauge. The proportion of non-paying to paying load has been taken at 4 to 1 on the broad gauge, although it has proved largely in excess of this. The wagons employed average 4 tons in weight, so that on this reckoning each wagon carries 1 ton for every mile it runs. It would be well to remember here that I am dealing with things as they are, not as they might be.

The wagons for a line of 3-ft. gauge weigh each 1 ton, and carry a maximum load of 3 tons. Supposing that the same number of wagons and trains were run on the narrow gauge as on the broad, it follows that the average 1 ton of merchandise now carried would easily be taken in a wagon weighing 1 ton instead of 4 tons, and that the gross load passing over the line for 1 year would be only 20,000,000 tons instead of 50,000,000; whilst the same amount of paying weight would be carried in either case. That is, the small wagons, which are capable of carrying 3 times the weight of goods now actually carried in a 4-ton wagon, would only have to carry ¼ of that quantity, and would produce the same paying load as the heavier wagons; thus, instead of 50,000,000 of tons travelling over the line, there would only be 20,000,000, and, as the haulage cost is precisely the same whether the tons hauled consist of paying or of non-paying load, it follows that this expense would be reduced to ⅖ of what it now is. We must also consider the enormous saving to the permanent way, which would have to bear the friction and weight of only 20,000,000 tons in the place of 50,000,000. If we assume the same number of trains to run per day, the weight of each would be reduced from 255 tons to 102 tons; or, if the same gross weight of train was employed, the number of trains per day would be reduced from 626 to 250. If there should be sufficient traffic to load the narrow-gauge wagons in such a way as to require the same number and weight of trains that are now worked, the result would be that, without increasing by one penny the cost of haulage and of the permanent way expenses, the 3-ft. gauge would carry a paying load of 25,000,000 tons as against the 10,000,000 now carried. Here, then, we have established the fact that, so far as capacity goes, the narrow gauge is superior to the broad one. The former can produce 25,000,000 net out of a gross tonnage of 50,000,000; whilst the latter, to produce the same result, if continued to be worked as it now is, would require that 125,000,000 tons should be hauled, and that at an increased cost in the same proportion of 125,000,000 to 50,000,000.

It may occur to some of my hearers to ask at this stage whether locomotives can be built to haul large train loads on a 3-ft. gauge at the same speeds at which such loads are now taken on the broad gauge—my answer to this is decidedly "Yes."

The Fairlie double bogie engine cannot only be made to haul trains fully as heavy and at the same speeds as those now taken on the broad gauge; but it will do this on what is termed a light railway, with rails that shall not be required to exceed 50 lbs. to the yard, and that shall be fairly worn out, instead of being crushed and ground out as the 84 lbs. rails are under the present system.

It will be seen from this that a very large and important saving could be effected on the London and North-western Railway, if its gauge were 3 ft. instead of 4 ft. 8½ in., without changing in the least degree its present system of management; and that this saving, di-

vided between the public and the shareholders, would largely reduce the tariffs to the one, whilst it as largely increased the dividends to the other.

Before entering on another example of the advantages of the narrow gauge, it will perhaps be well to explain why it is that the average paying-load now carried on the Northwestern Railway bears so small a proportion to the weight of the wagons employed in carrying it. The reason is obvious enough. The railway covers a very large area of country, and penetrates into districts from which there is a very unequal traffic; so that there must be a large average of empty wagons passing from one place to another in order to accommodate this traffic. It is impossible to find the same tonnage leaving a station that enters it. There is also great competition for the traffic; since most, if not all, of the large towns touched by this railway are also supplied by one or more lines belonging to other companies, and the inhabitants, having a choice, take care to avail themselves of it by fighting one company against the other. The result is, that each company tries to outbid its neighbor, not only in rates of charge, but also in affording the greatest despatch. This practically amounts to a competition as to which company shall run the greatest number of half filled or empty wagons.

Suppose, for example, that a person delivers a bundle of chairs, or a quantity of any goods, at a station, to be forwarded to some other station. The station-master cannot keep the chairs or other goods until he has a wagon load going to the same place; but must despatch them forthwith, perhaps alone in a wagon that ought to carry 10 times the quantity. But whatever may be the explanation of the small proportion of paying to non-paying load, the fact must in any case tell in favor of the narrow gauge. Suppose even that the wagons always ran empty one-half their time. Take the case of coal wagons, which run full only one way, and return empty. The narrow gauge still has the advantage, for they are only 1 ton wagons that run empty instead of being 4 ton wagons. In the case of the bundle of chairs there would only be the actual weight of the chairs added to that of the 1 ton wagon, instead of to the weight of a 4 ton wagon; so that, however the matter is looked at, it will always be found that the advantages on the score of economy are enormously in favor of light narrow gauge railways.

In India the competition between companies does not exist, and it is possible to detain goods at stations until a maximum quantity is obtained for transport. Time is there of little importance, and hence it has been urged that under such circumstances a large gauge and large wagons are the best, in order that it may be practicable to run a small number of heavy trains per day.

It is impossible to conceive an argument more fallacious than this; and its employment has saddled India with the commencement of a system of railways extravagantly beyond the requirements of the country for the next hundred years, or even for ever.

I have just shown that a 3-ft gauge-line can carry, without an additional shilling for haulage, $2\frac{1}{2}$ times as many tons as are now carried over the 4 ft. $8\frac{1}{2}$ in. gauge of the Northwestern Railway. Whence then arises the necessity for constructing the Indian Railways on a 5 ft. 6 in. gauge? especially when it is remembered that the total goods traffic worked over the whole of them does not amount to a sixth part of that now carried on the Northwestern Line alone.

Taking the case of the East India Railway as being the Northwestern of India, let us see how the absence of competition and the 5 ft. 6 in. gauge affect the question of transport. The number of net tons hauled over the line for the year ending 1869, was 938,629, in 32,490 trains; amounting to about 29 tons per train. The average number of wagons composing a train is taken at 25, of 6 tons each; which gives 150 tons of train or 29 tons of freight, or a proportion of over 5 tons of dead to 1 ton of paying load. It will be seen that, notwithstanding the absence of competition, and with everything to favor the working of the line, the actual dead weight is over 5 tons to 1 ton. If, on the other hand, the gauge had been 3 ft. instead of 5 ft. 6 in., the dead weight, under the same management, would have been reduced from 5 to 1, to $1\frac{1}{4}$ to 1. Let us imagine the saving that this change would effect in fuel alone; considering that less than one-fourth of the tonnage now hauled would afford precisely the

same accommodation to the traffic that now exists, and would produce the same paying result. It surely does not require a philosopher to see that the narrow gauge is infinitely superior in every respect even to the 4 ft. 8½ in. gauge, and it ought to be engraved on the mind of every engineer that *every inch added to the width of a gauge beyond what is absolutely necessary* for the traffic, *adds to the cost of construction, increases the proportion of dead weight, increases the cost of working*, and in consequence *increases the tariffs to the public*, and by so much *reduces the useful effect of the railway*. Let us suppose for one moment that the conditions of the cost of construction in the two instances were reversed, and that a 3 ft. gauge line would cost twice as much to make as a 5 ft. 6 in. gauge, even in such a case the difference in the cost of working each ton of goods would be so enormous that the narrow gauge would be by far the cheapest of the two in the end. It is unnecessary to say that the cost of constructing a railway is nearly as the width of its gauge ; in very rough countries the narrow guage will be greatly less than the proportion to its width, whilst in flat level ground the proportion will be more ; but, taking the average (excluding rolling stock, fencing, stations, and telegraphs), the cost will be found to vary as the gauge. The advocates of the 5 ft. 6 in. gauge, not content with the burthen which they have imposed upon India, are striving to impose a similar burthen upon our Colonies, and in too many instances they have actually succeeded. The Colony of Victoria, for example, has been provided with a system of 5 ft. 6 in. gauge railways, which are so magnificent and costly that they charge the Colonial revenue with a trifling deficit of £30,000 per annum.

Tasmania, under the same management, has been saddled with a railway of 5 ft. 3 in. gauge. There are other places similarly situated, but to mention them all would prolong this paper beyond its proper limits. I have shown sufficient evidence to prove what I said at the commencement ; and, through the medium of this great Association, I desire to inform the inhabitants of countries in which railways are required, how these can be obtained cheaply and efficiently. In moderately temperate climates, gauges of 2 ft. 6 in. will be found ample for any traffic in any part of the world, and will sustain a speed of 30 miles an hour ; while 3 ft. is sufficient for either very hot or very cold climates, and will sustain a speed of forty miles an hour.

Railways can be made cheaply, and at the same time, to be thoroughly efficient ; and those who aver to the contrary are, in fact, enemies to progress and to civilization. There is no country too poor to have railways sufficient for its requirements ; and railways furnish the cheapest possible mode of transport when they are not borne down by the result of that incompetence and extravagance which we so often see associated together. I regard it as the duty of every man in the old country to assist those in the new by pointing out how they may benefit by our dear-bought experience, and may avoid the pitfalls into which only too many of our Railway Shareholders have fallen.

The present railways in India, although doubtless valuable for military purposes, have cost about £20,000 per mile. The average rate per ton paid on the East Indian Railway is 2¼d. per ton per mile. It may be fairly questioned how far these lines are boons to the inhabitants, who are called upon to pay taxes to cover the heavy annual interest on the cost, as well as to pay the high tariff of rates mentioned above. In any Indian extensions it should clearly be our aim to satisfy the natives, and to develop traffic at their hands. How different would the results have been, even now, if the lines had cost £5,000 instead of £20,000 per mile, and if the tariff of rates had been ¼d. per ton per mile instead of 2¼d. Not only would this have been practicable if the narrow gauge had been adopted, but the charge for the conveyance of salt, one of the first necessaries of life in the country, need not have exceeded ¼d. per ton per mile.

I cannot close this paper without some reference to a matter that is now part of history, and that serves as an admirable illustration of the manner in which self-interest, or even mere conservatism, may render men blind to the most obvious propositions. There are some whose whole desire it seems to be to rest in the paths that they have become accustomed to tread ; and whose instincts lead them at once to turn and rend any one that proposes a change. In January last my

presence was hurriedly required in St. Petersburg by the Russian Minister of Public Works, with reference to the subject of the Fairlie system of railways, to which attention had been called by the very able articles upon the "Railway Problem," which appeared in "The Times" on the 19th, 20th, and 21st October, 1869. (A reprint of these articles will be found on the table.) His Excellency the Minister required me to give a short distinct account of the advantages claimed for my system. I replied, that by the adoption of that system railways could be made at a cost of little over one-half the sum required to construct them on the ordinary plan; so that it would be possible to give nearly *two* miles for the sum now expended upon one. That these lines, when finished and equipped, would possess a carrying capacity equal to, if not greater than that of those on the old system. In other words, they should be capable of carrying as many passengers and tons of goods in twenty-four hours as the best lines now existing; and that this should be done at a reduced cost, independently of the reduced wear and tear to the permanent way, and of the value of the increased life of the rails. His Excellency observed, that if only a portion of this could be accomplished, it would be a great thing for Russia, and that the matter should be at once inquired into. Not many days elapsed before an Imperial Commission, composed of a number of the most noted scientific men in Russia, and presided over by His Excellency the Count Alexis Bobrinskoy, private Attache to his Imperial Majesty the Emperor, was instructed to come to this country and to investigate the correctness of what I had asserted. Early in February the Commission arrived in London, and after a thorough examination of the question in all its theoretical bearings, it was resolved to put it to some practical tests. The Council of India, the Board of Trade, Norway, France, and other countries sent their representative men to be present on the occasion, as it was felt that what was good for Russia would be equally good for the countries I have mentioned. His Grace the Duke of Sutherland, always anxious to promote any system that will most largely benefit mankind, and having already a large section of railways of his own, built expressly to improve the condition of his tenantry, joined the party, and took a most active interest in all the proceedings. The results of the experiments then made are pretty well known, and any who may not be acquainted with them will find printed records of them on the table.

The Commission returned to Russia, and sent in its report to the effect that I had fully proved the correctness of all my assertions. This was in March, and in April a railway of fifty versts, on the new system, was ordered by his Majesty the Emperor to be constructed, and to be opened in November next. The locomotives for this railway may be seen any day during the next month at the establishment of Messrs. Sharp, Stewart, and Co., Manchester. The new system has also been adopted for working some of the old lines, and the stock for the Tamboff Saratoff Railway, the Great Russian, and others, may be seen under construction at the same establishment.

The members of the Council of India were so struck with the accounts of the system, that the Home Engineers of the several Indian railways were requested to report to their respective Boards their opinions on the applicability of a new narrow gauge for India. I have seen several of these reports, the whole of which are unanimous in their opposition to any improvement, or to any interference with the system under which the writers have lived, and moved, and had their being; but in only one of them is there any argument that requires a moment's notice. Mr. Hawkshaw, in his Report to the Directors of the Eastern Bengal Railway, urges that, since those who are in favor of a narrow gauge argue upon the basis of a light rolling stock, the same basis should also be taken by the advocates of a broad gauge. Were it not for this attempt at reasoning, and also for the fact that Mr. Bidder very fiercely attacks both me and my system, I should have left the reports wholly without mention. But I think it is worth while to reply to Mr. Hawkshaw, and also to place on record that Mr. Bidder has evidently never seen my system, although often invited to do so; and that he has based his condemnation of it upon an utterly incorrect description, both as regards principles and details.

The claim to calculate for broad gauge lines on the basis of lighter rolling stock,

is practically an admission that grave errors have been made in designing that which is now in use, and which it is proposed theoretically to set aside while the question of gauge is under discussion. But however Mr. Hawkshaw may build his stock in the future, he cannot possibly build it so light and capable of doing so much duty for the broad as for the narrow gauge. His argument is a complete confession of the mistakes made under the old regime ; whilst at the same time it is an attempt to extinguish the general wish to inquire into the merits of the new. It is asking to be forgiven for the past, with a promise to do better in the future,—or to do anything rather than permit clients to go to a new school.

It is a sad incident in the great history of human error when we thus find men led into such mistakes as these by their anxiety to resist innovation. How different would be the course of invention, how smooth the path of improvement, what years of anxious labor would be saved to many of us, if such men would lay aside all rivalries, and would bring their helping hands to the good work of progress.

THE SOLAR ENGINE.

By Captain JOHN ERICSSON

From "Engineering."

On grounds which will appear hereafter, it is not my intention at present to enter on a minute description of the solar engine. I feel called upon, however, in order to remove prevailing erroneous impressions on the subject, to state briefly the general features of my scheme. At the same time, let it be understood that the solar engine is not intended as a competitor with the steam-engine, where coal can be obtained ; nor is it proposed, in the first instance, to erect this motor where there is not continuous sunshine.

The accompanying illustration, which derives its chief interest from the fact that it represents a piece of mechanism actuated by the direct agency of solar heat, is copied from a photograph of a small solar engine just completed, intended as a present to the French Academy of Sciences. Apart from being a motor, this engine has been designed to operate as a meter for registering the volume of steam generated by the concentrated heat of a sunbeam of a given section. Regarded as a steam meter, it is important, as it verifies the results of previous experiments and previous calculations based on the number of units of heat developed in evaporating a certain weight of water in a given time. Engineers will not fail to notice the unusual proportions of the working parts, nor will they fail to appreciate the object in view, that of reducing the friction to a minimum—an indispensable condition in a meter. The entire mechanism being shown with perfect distinctness, it is only necessary to explain that the square pedestal which supports the steam cylinder (4½ in. in diameter), the beam centre, and the crank shaft, conceals a surface condenser.

Under a clear sun the engine which our illustration represents runs, with perfect uniformity, at a fixed rate of 240 revolutions per minute, consuming at this rate only part of the steam furnished by the solar steam generator, now temporarily employed, belonging to an engine of greater dimensions constructed some time ago. With reference to ascertaining the amount of mechanical power developed by the solar engines, engineers need scarcely be reminded that, by dispensing with a vacuum, the atmospheric resistance and back pressure exerted against the pistons furnish accurate means for measuring the dynamic force transmitted by sunbeams of definite sections.

Plans and descriptions of the mechanism by which the sun's radiant heat is concentrated, and of the steam generator which receives the concentrated heat, I shall be compelled, for some time, to withhold from publication. Experienced professional men will appreciate the motive, that of preventing enterprising persons from procuring patents for *modifications*. In connection with the course thus deemed necessary, it will be proper to mention that I have in several instances, notably in the case of the screw propeller and the caloric engine, been prevented from perfecting my invention in consequence of

conflicting privileges having in the mean time been granted to others.

Regarding the solar engine, I avail myself of this opportunity to say that I shall not apply for any patent rights, and that it is my intention to devote the balance of my professional life almost exclusively to its completion. Hence my anxiety to guard against legal obstructions being interposed before perfection of detail shall have been measurably attained. Within a few years the entire engineering community of both hemispheres will be invited to take the matter in hand. In the meantime let us hope that no exclusive privileges may be granted tending to throw obstacles in the way of an unrestricted manufacture and introduction of the new motor wherever it may be applicable.

The foregoing having introduced the subject, let us now enter upon a cursory examination of the merits of the solar engine. The several experiments that have been made show that the mechanism adopted for concentrating the sun's radiant heat abstracts, on an average, during nine hours a day, for all latitudes between the equator and 45 deg., fully 3.5 units of heat per minute for each square foot of area presented perpendicularly to the sun's rays. A unit of heat being equivalent to 772 foot-pounds, it will be perceived that, theoretically, a dynamic energy of 2702 foot-pounds is transmitted by the radiant heat, per minute, for each square foot; hence 270,200 foot-pounds for an area of 10 ft. square. If we divide this sum by the adopted standard of 33,000, we ascertain that 100 squre feet of surface exposed to the solar rays develop continuously 8.2 horse power during nine hours a day, within the limits of latitude before mentioned. But engineers are well aware that the whole dynamic energy of heat cannot be utilized in practice by any engine or mechanical combination whatever, nor at all approached; hence I have assumed, in order not to overrate the capability of the new system, that a solar engine of 1-horse power demands the concentration of solar heat from an area of 10 ft. square. On this basis I will now proceed to show that those regions of the earth which suffer from an excess of solar heat will ultimately derive benefits resulting from an unlimited command of motive power which will, to a great extent, compensate for evils hitherto supposed not to be counterbalanced by any good. Before entering on this task of estimating the results of utilizing sun power, it will be well to scrutinize, as closely as we can, the mechanical devices by means of which we propose to avail ourselves of the fuel contained in that great store-house from whence it may be obtained free of cost and transportation. The solar engine, we have seen, is composed of three distinct parts. The engine, the steam generator, and the mechanism by means of which the feeble intensity of the sun's rays is augmented to such a degree that the resulting temperature will exceed that of the lowest pressure of steam admissible in an efficient engine. As to the motor itself, it suffices to say, that it is essentially a modern steam engine utilizing, to the fullest extent, the mechanical energy of the steam generated by the concentrated solar rays. Regarding the steam generator, it will only be necessary to state that it is not exposed to the action of fire, clinkers, or soot, and therefore can only suffer from the slow action of ordinary oxidation. We have lastly to consider the efficiency of the mechanism by means of which the solar heat is concentrated and the temperature raised above that of the water in the steam generator. Regarding this mechanism—concentration apparatus it may appropriately be termed—it will be asked: is it costly? is it heavy and bulky so as to render transportation difficult? and finally the question will be put, is it liable to derangement and expensive to keep in order? I will answer these questions in the same order in which they have been presented. The cost is moderate. The weight is small—indeed lightness is the most notable peculiarity of the concentration apparatus. As to bulk, this apparatus is composed of small parts readily put together. Regarding durability, the fact need only be pointed out that certain metals however thin, if kept dry, may be exposed to the sun's rays during an indefinite length of time without appreciable deterioration; hence, unlike the furnaces of steam boilers, which soon become unserviceable, structures protected as the concentration apparatus is, by thin metallic plates, cannot be rendered unserviceable from the mere action of the sun's rays. Another question will be asked, whether the solar engine will answer as

well on a large as it does on a small scale? The following reply will effectually dispose of this pregnant query. It is not necessary, nor intended, to enlarge in future, the size of the apparatus by means of which the solar intensity has been successfully concentrated and the temperature sufficiently elevated to generate steam for the engines which have been built. The maximum size adopted has been adequate to utilize the radiant heat of a sunbeam of 35 square feet section. The employment of an increased number of such structures will therefore be resorted when greater power is wanted, as we increase the number of hands when we desire to perform an additional amount of work. The motor itself, the steam cylinder and other parts, will obviously be proportioned as at present with reference to the pressure of steam employed and the work to be done.

Agreeable to our introductory remarks, it is not proposed in the first instance, to apply solar engines in places where there is not steady sunshine. The isolated districts of the earth's surface suffering from an excess of solar heat being very numerous, our space only admits of a glance at the sunburnt continents. An examination of the extent of these will show that the field for the solar engine, even with the proposed restriction, is not very contracted. There is a rainless region extending from the northwest coast of Africa to Mongolia, 9000 miles in length, and nearly 1000 miles wide. Besides the Northern African deserts, this region includes the southern coast of the Mediterranean east of the Gulf of Cabes, Upper Egypt, the eastern and part of the western coast of the Red Sea, part of Syria, the eastern part of the countries watered by the Euphrates and Tigris, Eastern Arabia, the greater part of Persia, the extreme western part of China, Tibet, and lastly, Mongolia. In the western hemisphere, Lower California, the table-land of Mexico and Guatemala, and the west coast of South America, for a distance of more than 2000 miles, suffer from continuous intense radiant heat.

Computations of the solar energy wasted on the vast areas thus specified would present an amount of dynamic force almost beyond conception. Let us, therefore, merely estimate the mechanical force that would result from utilizing the solar heat on a strip of land, a single mile in width, along the rainless western coast of America; the southern coast of the Mediterranean before refered to; both sides of the alluvial plain of the Nile in Upper Eygpt; both sides of the Euphrates and Tigris for a distance of 400 miles above the Persian Gulf; and, finally, a strip one mile wide along the rainless portions of the shores of the Red Sea, before pointed out. The aggregate length of these strips of land, selected on account of being accessible by water communication, far exceeds 8,000 miles. Adopting this length and a width of one mile as a basis for computation, it will be seen that the assumed narrow belt of the sunburnt continents covers 223,000 millions of square feet. Dividing this by the area necessary to produce 1-horse power, we learn that 22,300,000 solar engines each of 100-horse power, could be kept in constant operation, nine hours a day, by utilizing only that heat which is now wasted on a very small fraction of the land extending along some of the water fronts of the sunburnt regions of the earth.

It will be said that these extravagant figures are devoid of practical significance. Due consideration, however, cannot fail to convince us that the gradual exhaustion of the coal fields will inevitably cause great changes in regard to international relations, in favor of those countries which are in possession of continuous sun power. Upper Egypt, for instance, will, in the course of time, derive signal advantage, and attain a high political position, on account of her perpetual sunshine and the consequent command of unlimited motive force. The time will come when Europe must stop her mills for the want of coal. Upper Egypt, then, with her never ceasing sun power, will invite the European manufacturer to remove his machinery and erect his mills on the firm ground along the sides of the alluvial plain of the Nile, where sufficient power can be obtained to enable him to run more spindles than a hundred Manchesters.

I reserve for another occasion, the consideration of the important question: To what extent can the irregular sunshine of Europe be rendered available in producing a regular motor, by the expedient of alternately accumulating and drawing upon reserved force?

PNEUMATIC TRANSMISSION THROUGH TUNNELS AND PIPES.*

By ROBERT SABINE.

From "Engineering."

Some months since I had occasion to assist in designing the extension of a pneumatic despatch line in which some heavy gradients were, from considerations of economy and the peculiar nature of the land, unavoidable. It became, therefore, necessary to ascertain by calculation the steepest gradient which we could venture to employ, so as to obtain a sufficient carrying capacity in the new section of the line under given conditions of engine power and of length. On referring for information to text-books and the papers of various authorities on the velocity of gases in pipes, I found that almost every one of them gave a different formula, so that by some a very high, and by others a very low rate of transmission was promised under identically the same circumstances. I was further disappointed at failing to find in any of the ready-made formulæ which I was in possession of that the weight and friction of a piston or carrier were taken into account.

The conditions of motion in a pipe through which gas is simply blown—passing in at one end and out at the other—are different from those of a tube through which the gas has to propel a piston. When the gas alone passes through, it expands gradually and regularly in the whole length of the tube, from the higher pressure at one end to the lower pressure at the other. But when a carrier, whose motion offers considerable resistance, is inserted, it is driven forwards with a mean velocity corresponding to that with which the air at the higher pressure is introduced behind it, or that at the lower is exhausted in front of it. For if the compressed air were introduced or the rarefied withdrawn with a greater velocity than that of the carrier, the higher pressure would increase or the lower diminish; if with less velocity, the reverse would take place. It is found, however, in working pneumatic tubes, that the higher and lower pressures both remain practically constant during the whole transmission.

Under these circumstances, I found it necessary to attempt to construct a convenient expression for the speeds of carriers of given weight and friction, under various conditions of pressure, gradients, and dimensions of tube, which, although not of necessity strictly theoretically correct, would nevertheless be correct within the errors of observation of its component values, and therefore sufficiently so for all practical purposes.

In dealing with a pneumatic tube, we are fortunately enabled to do this without any elaborate calculation, because we require only to ascertain, under given conditions, the time of transmission of a carrier from one end to the other, or its mean velocity; its actual velocity, at any given point of the length, whether greater or less than the mean, being of no practical importance.

The problem of a successful pneumatic system is simply this: To make a given quantity of air expand from one pressure to another in such a way as to return a fair equivalent of the work expended in compressing it. It is obviously impossible to regain the full equivalent of the work, because the compression is attended with the liberation of heat, which is dissipated and practically lost to us. Therefore, in designing a pneumatic system, that which we have to do is first to contrive means of compressing the air as economically as possible; secondly, to get back as much as we can of the mechanical effect stored up in our already compressed air, irrespectively of the work which was employed in compressing it.

The utmost theoretical work which a given quantity of air can be made to perform, is evidently that of expanding from the higher to lower pressure; and the mechanical effect employed in propelling a carrier and air through a given tube is therefore equivalent of that due to the expansion of a tubeful of air from the higher to the lower pressure.

If the volume of the tube be v, cubic feet, and the mechanical effect performed by a cubic foot of atmospheric air in expanding from the higher pressure to the lower be f (foot pounds), then the work,

* Paper read before the British Association (Section G) at Liverpool.

F, performed by the whole tubeful of compressed air will be

$$F = v f \text{ foot pounds.}$$

The mechanical effect, f, performed by one cubic foot of air in expanding from p_1 to p_2 (lb. per square inch) pressure is

$$f = 144 \frac{1}{n-1} p_1 \left[1 - \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} \right] \text{ foot pounds.}$$

in which n=1.408, the relation between the specific heat of dry air when maintained at a constant pressure, and when maintained at a constant volume.

Inserting the numerical value of n, for one cubic foot:

$$(1)\quad f = 352.94\, p_1 \left[1 - \left(\frac{p_2}{p_1}\right) 0.29 \right] \text{ foot pounds,}$$

and for the whole tubeful:

$$(2)\quad F = 352.94\, p_1\, v \left[1 - \left(\frac{p_2}{p_1}\right) 0.29 \right] \text{ foot pounds.}$$

In driving a carrier through the tube, we expend this mechanical effect in accelerating the carrier and the air, and in sustaining them both in motion. The work expended in accelerating the air, we will call A. And if the weight of a cubic foot of air at the higher pressure be w_1 lb., and that of a cubic foot at the lower pressure, w_2 lb., this work of acceleration,

$$(3)\quad A = \frac{w_1 + w_2}{2}\, v\, \frac{s^2}{2g} \text{ foot pounds,}$$

s being the mean velocity of motion, and g the acceleration by gravity, both in feet per second.

The work expended in accelerating the carrier we will call B. This work is expressed by

$$(4)\quad B = W \frac{s^2}{2g} \text{ foot pounds,}$$

W being the weight of the carrier in pounds.

After the air and carrier have been accelerated until they assume a mean velocity, s, feet per second, which we will suppose to be constant, the remaining work applied to propel them is, of course, consumed in keeping up this velocity, that is to say, in overcoming their resistance to motion. The mechanical effect, C, absorbed by resistance to motion of air in passing through a tube of the length, l feet, and diameter d feet, is

$$(5)\quad C = \zeta \frac{l}{d} \cdot \frac{w_1 + w_2}{2} \cdot v \frac{s_2}{2g} \text{ foot pounds.}$$

This item in the expenditure of power is more important than any of the rest, amounting, in general cases, to at least ten times all the others put together.

There exists no definite and satisfactory determination of the value of the empirical constant (ζ), which probably varies slightly, not only with the diameter, the material, and the condition of the surfaces of the tube, but likewise with the density of the air which is passing through. Experiments to determine its value have been made by Girard, D'Aubuisson, Buff, Pecqueur, and others, who give a mean value for it of 0.02.

Lastly, the work (D) consumed in friction of the carrier is

$$(6)\quad D = W l (\sin \alpha + \mu \cos \alpha) \text{ foot pounds,}$$

in which $\alpha°$ is the angle made by the tube with the horizon, and which is + when the carrier ascends, but — when it descends; μ is the coefficient of friction of motion of the carrier in the tube.

We have, therefore, the value F, foot-pounds of work, balanced by the items of expenditure (A+B+C+D) or

$$(7)\quad F = A + B + C + D.$$

Setting the algebraical values in this equation

$$(8)\quad vf = \frac{w_1 + w_2}{2}\, v\, \frac{s^2}{2g} + W \frac{s^2}{2g} + \zeta \frac{l}{d} \frac{w_1 + w_2}{2}\, v. \frac{s^2}{g} + W l (\sin \alpha + \mu \cos \alpha)$$

From which we obtain the mean velocity (s) with which the carrier travels.

$$(9)\quad s = \sqrt{2g \frac{v f - W l (\sin \alpha + \mu \cos \alpha)}{W + \frac{w_1 + w_2}{2} v \left(1 + \zeta \frac{l}{d}\right)}} \text{ feet per second}$$

when going up or down an incline.

But when the tube is level or may be taken as level, α=0,

$$(10)\quad s = \sqrt{2g \frac{v f - W l \mu}{W + \frac{w_1 + w_2}{2} v \left(1 + \zeta \frac{l}{d}\right)}} \text{ feet per second}$$

If this formula is correct, it should be equally so for small and for large tubes; therefore, we should get equally concordant results in comparing it with experimental data obtained both with parcels tubes and with small letter tubes.

The results of experiments which I am in possession of are very limited in number, but they suffice to prove the general application of the formulæ. The first illustration is the performance of the tube

of the Pneumatic Company, between Euston Station and High Holborn, which was some years ago designed by and carried out under the engineering superintendence of Mr. Rammell and Mr. Latimer Clark. This tube is ⊓ shaped, 4½ ft. broad and 4 ft. high. The tube and its machinery were out of use for some years until it was found desirable recently to employ them in transporting a quantity of materials from Euston Station to Holborn. The trains used were each made up of three trucks, and these were loaded with an average weight of 6 tons, making with the carriages a gross load of 9 tons. The average time occupied in running through the tube from Euston Station to Holborn was 7½ minutes, with a partial vacuum of 5 oz. per square inch, whilst the empty trucks were returned to Euston Station with a compression of 5 oz. per square inch in 6½ minutes. From this we have, therefore, data for two calculations, one way with a load of 9 tons, and the other with a load of 3 tons. We may assume the mean temperature of the air was 20° C, and its mean pressure 14.75 lbs. Therefore, in drawing the loads through to Holborn the air was exhausted to 14.44 lbs., and in sending back the empty carriers it was compressed to 15.06 lbs. per square inch.

With these data, equation 1 gives the mechanical effect, f, due to the expansion of one cubic foot of the air in the two experiments.

Experiment No. 1 (Exhausting).
$f = 31.964$ foot-pounds.
Experiment No. 2 (Compressing).
$f = 31.945$ foot-pounds.

To find the speed of the trains in each case, by formula 10, we have also the data:

For Experiment 1.
$w_1 = 0.07533$ at 20° C.
$w_2 = 0.07302$ at 18.2° C.]
W = 21600 lbs.
For Experiment 2.
$w_1 = 0.07747$ at 21.1° C.
$w_2 = 0.07524$ at 20° C.
W = 6720 lbs.

And the common values,

$l = 9075$ ft.
$d = 4\ 5$ ft.*
$v = 145{,}200$ cubic ft.

whilst the coefficient of rolling friction of these carriers I found to be 20 lbs. to the ton, therefore,

$$\mu = \frac{20}{2240}$$

These values inserted in formula 10, give the speed as follows:

Experiment 1 (Exhausting).
$s = 20.41$ ft. per second, or 13.91 miles per hour.
Experiment 2 (Compressing).
$s = 23.81$ ft. per second, or 16.24 miles per hour.

And the time occupied in transit from end to end was therefore:

Experiment No. 1, 7 minutes 25 seconds.
Experiment No. 2, 6 minutes 21 seconds.

Whereas we found the time to be 7 minutes 30 seconds in one direction, and about 6 minutes 30 seconds in the other. This result is therefore sufficiently accordant to indicate the correctness of the formula for tubes of this size.

With small tubes the experiments upon velocity are scantily recorded, but I find one of a tube 2½ in. in diameter, laid down some years ago by Messrs. Siemens, at Berlin, between the Exchange and Central Telegraph Station. The report is by Dr. P. Brix, Professor at the Bau-Akademie, and is published in the German "Telegraph Journal."†

He gives the following data, obtained for the purpose of finding the different speeds with equal pressure and vacuum:

"Bei einem zu diesem Zweck augestellten Versuch, bei welchem Ueberdruck . . . . und Unterdruck . . . gleich waren, nämlich 9 zoll Quecksilber, fand sich die Beförderungszeit eines Wagens nach der Börse hin 90 secunden und vonder Börse nach dem Telegraphen gebaude Zurück 70 secunden."

We have, therefore, assuming the tension of the air at the middle point of the line to have been a mean between those of the reservoirs at the pumping station:

Ex. 1 (Compression.	Ex. 2 (Exhaustion.
$p_1 = 19.31$ lbs.	$p_1 = 14.75$ lbs.
$p_2 = 14.75$ lbs.	$p^2 = 10.19$ lbs.

whence by equation (1) supposing the temperature of the outer air to have been 20° centigrade:

Experiment 1 (Compression).
$f = 512.17$ foot-pounds.
$w_1 = 0.1099$ "
$w_2 = 0.0753$ "

* The value of d, which I have given here, represents the equivalent diameter; that is to say, that diameter which, with a tube of circular section, would give the same area as the one under consideration.

† Die pneumatische Depeschenbeförderung Zwischen der Central-Telegraphen station in Berlin und den Börsengebäude daselbst. Zeitschrift des Telegraphen-Vereins-Jahrgang xiii., p, 109.

Experiment 2 (Exhaustion).
f = 529.44 foot-pounds.
w_1 = 0.0752 "
w_2 = 0.0447 "

And for each the common values: $W\mu$ —the frictional resistance of the carriers in the tube—averaged 0.1 lb.; the length, l, is 2,920 for each half of the tube; its diameter, d, is 0.193 ft.; and its volume (v) = 85.49 cubic feet.

With these values, formula 10 gives us the calculated speeds in these two experiments:

(Compression).	(Exhaustion).
s = 34.1 ft. per second.	s = 43.2 ft. per second.

or that the carrier should have occupied in the transit from station to station, whilst compressing, 86 seconds; whilst exhausting, 68 seconds.

For compression, therefore, our formula gives the time 9 seconds less than that observed by Dr. Brix, a difference due possibly to an error of observation of the pressure, possibly also to the fact that the constant ζ may not be the same for small welded iron tubes as for a large cast-iron tunnel. The difference, however, between the calculated and observed values of the time of transmission by exhaustion is only 2 seconds.

A long length of pneumatic letter line is in contemplation in London in connection with the Post Office telegraphs. When this is at work, I trust to obtain permission to make a series of observations with a view of determining the value of the empirical constant (ζ) for small tubes. The approaching completion of the Pneumatic Company's parcels line with its extension to the General Post Office will enable a series of valuable experiments to be made having a direct bearing upon the future employment of pneumatic propulsion for trains in long tunnels.

In the meantime, I think that the experiments which I have cited were made under sufficiently various conditions, and are sufficiently concordant when compared with the foregoing formula to justify us in assuming, for the moment, that the latter is approximately correct. If so, we are in a position to trace the relations existing between speed, work, performance, and dimensions when the train or carrier is supposed to be so light that we may set the value W=0 in formula 10, which becomes therefore,

$$(11)\quad s = \sqrt{2g\frac{f}{\frac{w_1+w_2}{2}\left(1+\zeta\frac{l}{d}\right)}} \quad \text{feet per second.}$$

And when the tubes are very long in comparison with their diameters, that is to say, when the length exceeds 5,000 times the diameter, we may in practice write the formula thus:

$$(12)\quad s = \sqrt{2g\frac{}{\zeta\frac{l}{d}\left(\frac{w_1+w_2}{2}\right)}}$$

or by setting,

$$f = \frac{F}{v}$$

in which the volume,

$$v = \frac{l\,d^2\,\pi}{2}$$

in the last quotation, we have the still more simple expression:

$$(13)\quad s = \sqrt{\frac{8g}{\zeta\pi}}\cdot\sqrt{\frac{F}{l^2\,d\left(\frac{w_1+w_2}{2}\right)}}$$

or inserting the numerical values of the constants,

$$(14)\quad s = 64\sqrt{\frac{F}{\frac{w_1+w_2}{2}}}\;\frac{1}{l\sqrt{d}}$$

It is evident by this equation, that in employing the same amount of mechanical effect, and the air remaining of the same mean specific gravity, the mean speed of transmission varies inversely with the length and inversely also with the square root of the diameter of the tube: Thus with an equal mechanical effect expended upon it in each case, a very light piston would travel through a tube of one mile long with exactly twice the speed with which it would travel through a similar tube two miles long. And further, if we had two tubes each a mile long, one having a diameter of 4 ft., and the other a diameter of 1 ft., the air in the larger tube would only travel half as fast as that in the smaller one, assuming, of course, the total work performed during the transit to be in each case equal. The cause of this is simply that the greater portion of the mechanical effect which in the larger tube is used for moving the greater mass of air, is, in the smaller one, converted into speed. If the case arose, therefore, that a pneumatic transit had to be made with a stated expenditure of work, we

should proceed economically, by adopting a tube of small rather than one of large sectional area.

This is, however, seldom or never the case, as in practice we are limited only to the utilizable power of our blowing machinery. Let this utilizable power be P foot-pounds per second; then,

$$P = \frac{F s}{l}$$

and

$$F = \frac{P l}{s}$$

Inserting this value of F in equation 14, the value of s becomes.

$$(15) \qquad s = 16 \left(\frac{P}{\frac{w_1 + w_2}{1}} \right)^{\frac{1}{3}} \frac{1}{(l\,d)^{\frac{1}{3}}}$$

This equation shows us that with an equal utilized engine power in each case, the mean speeds of transit of air through two tubes, are inversely as the cube roots of their diameters and lengths. For instance, with a utilized effect of 10-horse power, the velocity of transit in a tube eight miles long being 20 ft. per second, that attainable with the same power in a one-mile length of the same tube, would be 40 ft., and if we had two tubes of equal length, one eight times the diameter of the other, the speed attained in the larger tube would be only half that attained in the smaller.

If we had two tubes of different lengths (l and l_1), and of the different diameters (d and d_1) in both, which we wished to attain the same speed, we should have to employ the different utilized powers, P and P_1, and we should have the equation

$$\left(\frac{P}{l\,d\,\frac{(w_1 + w_2)}{2}} \right)^{\frac{1}{3}} = \left(\frac{P_1}{l_1\,d_1\,\frac{(w_1^{\frac{1}{2}} + w_2^{\frac{1}{2}})}{2}} \right)^{\frac{1}{3}}$$

whence, if the mean specific gravities of the air are equal, as in working by equal manometer indications of pressure and vacuum of the two ends of a tube, and the lengths are also equal

$$\frac{P}{d} = \frac{P_1}{d_1}$$

or,

$$P : P_1 = d : d_1.$$

Therefore, to obtain the same mean speed of transit of a very light piston, in two tubes of equal length, and different diameters, other things being equal, the utilized horse power must be directly proportional to the diameters. In the same way we find that if the diameters are equal ($d = d_1$), but the lengths (l and l_1) are unequal, to obtain equal speed in both,

$$P : P_1 : l : l_1;$$

that is to say, to produce in the same mean speed of transit of very light pistons in tubes of equal diameter, but different lengths, other things being equal, the utilized horse powers of engines may be taken as directly proportional to the lengths.

Similarly, when the lengths and diameters are equal ($l = l_1$ and $d = d_1$); but the mean specific gravity of air in the two operations are different:

$$P : P_1 = \frac{w_1 + w_2}{2} : \frac{w_1^{\frac{1}{2}} + w_2^{\frac{1}{2}}}{2}.$$

Therefore, the mean speed of a very light piston being the same, in its transits through the same tube or through two tubes of equal dimensions, the utilized engine power is directly proportionate to the mean specific gravity of the air on the two sides of the piston.

It follows from this, therefore, that in working by exhaustion, less engine power is required, other things being equal, than in working through the same tube by means of compression. And it would also follow that in hot weather, and when the barometer is low, the working of a pneumatic tube should be less costly in engine power than in cold weather, and when the barometer is high.

The influence of the state of the atmosphere upon the working of pneumatic lines (inappreciable of course in small tubes) would become of importance in working such pneumatic lines as that which has been proposed between France and England, supposing for the moment such lines to be possible.

In a tunnel 12 ft. by 13 ft., and 30 miles long, the air would weigh in winter, at the temperature of melting ice, about 750 tons. At the summer temperature it would weigh at the same atmospheric pressure only about 700 tons. Therefore the difference of temperature alone would effect a difference of 50 tons in the weight of air to be moved. Again, supposing the air at ice point to be under a barometer pressure of 31 in. of mercury, whilst at the summer temperature the barometer

fell to 29 in., the weight of air would in the latter case be reduced to about 550 tons, or 200 tons lighter than at the lower temperature and higher pressure. That is to say, the engine working such a line would have 200 tons less weight to move. We see, therefore, that if ever pneumatic engineering works should arrive at a point of development such as the tunnel cited as an imaginary illustration, atmospheric temperature and pressure would be by no means fanciful items in modifying the cost of their maintenance.

Turning back to formula 15, we see that with given utilized horse power operating upon a given line, the velocity of a very light carrier would be reciprocally proportional to the cube root of the mean specific gravity of the air moving in it. Mr. Siemens has proposed to take advantage of this fact by the employment of hydrogen gas for propulsion in letter tubes instead of atmospheric air. The specific gravity of hydrogen is 0.07, that of air being 1. The speed attainable, therefore, by the substitution of this gas would be as

$$1 : \frac{1}{(0{\cdot}07)^{\frac{1}{3}}}, \text{ or as 1 to } 2\tfrac{1}{2} \text{ nearly.}$$

This plan would be easily practicable with Messrs. Siemens's system of complete circuit tubes, in which the same air is pumped round without being changed. With any of the ordinary systems by which the tube is open at one end, of course only atmospheric air could be used in practice.

In conclusion, I think that the foregoing will serve to show that small pneumatic tubes may be worked more profitably than large ones. The great convenience of and practical facilities for working small letter-carrying tubes have been amply proved by the extensive systems already laid down in Paris, Berlin, London, and in other towns, as adjuncts to the telegraph services. Tubes of somewhat larger diameter, such as those proposed some years ago by Mr. E. A. Cowper, for the more speedy distribution of metropolitan letters to the branch post offices, would undoubtedly work satisfactorily. Even still larger tubes, if of moderate lengths, might also be found useful for a variety of special applications; for instance, in the transport of light materials between the different parts of a factory supplied with steam power. But I do not believe that a pneumatic line working through a long tunnel could, for passenger traffic, ever compete in point of economy with locomotive railways. A pneumatic railway is essentially a rope railway. Its rope is elastic, it is true, but it is not light. Every yard run of it, in a tunnel large enough to carry passengers, would weigh more than ¼ cwt. And it is a rope, too, which has to be moved against considerable friction; and in being compressed and moved wastes power by its liberation of heat.

In a pneumatic tunnel such as that proposed between England and France, in order to move a goods train of 250 tons through at the rate of 25 miles an hour, it would be necessary to employ simultaneously a pressure of 1½ lbs. per square inch at one end and a vacuum of 1½ lbs. per square inch at the other. The mechanical effect obtained with these combined—pressure and vacuum—would be consumed as follows:

In accelerating the air....	29	millions of foot-pounds.
In accelerating the train..	12	
By friction of the air.....5721		
By friction of the train...	330	

The resistance of the air, therefore, upon the walls of the tunnel would alone amount to 93 per cent. of the total mechanical effect employable for the transmission; while the really useful work would be only about 5½ per cent. of it. And to compress and exhaust the air to supply the above items of expenditure of mechanical effect, engines would have to exert over 2,000 horse power at each end during the transmission, even on the supposition that the blowing machinery returned an equivalent of mechanical effect such as has never yet been obtained. This would not be an economical way of burning coals. It is desirable, nevertheless, from an engineering point of view, that the merits and demerits of pneumatic parcels lines and pneumatic passenger lines which have been repeatedly suggested during the past half century should be thoroughly investigated. The works of the Pneumatic Company in London, which are approaching completion, will happily settle the question as regards parcels' tubes; whilst the pneumatic passenger railway, which I am told is in rapid course of construction under the streets of New York, will very soon either inaugurate a new era for city railways, or be written in the long list of unsuccessful experiments.

ON THE SEPARATION OF PHOSPHORIC ACID FROM IRON ORES AND IRON CINDERS.*

By JAMES HARGREAVES.

From "The Chemical News."

I need not here enter into any lengthened description of the evil effects of phosphorus upon iron; suffice it to say that iron containing phosphorus in appreciable quantities is utterly unfitted for the manufacture of steel, and is considerably deteriorated whether it is used in the form of cast or malleable iron. Hence it is desirable to get rid of the phosphorus to prevent its deterioration.

This subject had to some extent attracted my attention for several years, but not so far as to make it a matter of especial study and experiment; but, about five years ago, my attention was more closely drawn to the subject, and I proposed the use of alkaline nitrates as a means of converting cast-iron into steel, and at the same time, separating any phosphorus that might be present. By the use of nitrate of soda I have found it to be quite practicable to produce a good serviceable steel direct from phosphoric pig.

The process, however, was not carried out on a real working scale, for reasons entirely apart from its technical merits, to explain which would be to go into personal matters, which are quite foreign to the objects of this Association. But while engaged in the attempt to develop this steel process, the fact forced itself upon my attention that phosphorus had hitherto been too much looked upon as something to be *got rid of*, and not sufficiently as something to be *got hold of*; and that to effect the latter would be the best means of effecting the former. It was talked of and regarded by the iron manufacturers as "dirt," but that was because it was "matter in the wrong place," and the only way to make it cease to be dirt was to put it in the right one. I felt this to be a matter of considerable importance, and have often pressed as a subject of study by my fellow chemists, some commercially practical means of obtaining the phosphorus either alone or in some of its available compounds. I pointed this out in a paper read before the Liverpool Polytechnic Society, in November, 1867, and again before the Cleveland Institute of Engineers, at Stockton-on-Tees, in March, 1868. But at the latter place I was simply ridiculed for even alluding to anything so very preposterous, the very fact that there was such an immense amount of phosphoric ores consumed being quoted as a reason why the proposal should be considered impracticable. I refer those who are interested in this subject to the "Engineer" for the earlier part of 1868, for copies of the papers read at Liverpool and Stockton.

It seems, however, that no one has, so far as I can learn, thought proper to give this subject the attention which it deserves —not even those who are most interested in it, and whose opportunities and inducements must be very much greater than my own. In fact, it has almost seemed as if those who would naturally be expected to take the greatest interest in the subject are the last to pay any attention to it. It is one which I was anxious to see carried into practical operation, no matter by whom, as I looked, and still look, upon it as a question of not only pecuniary, but what is immeasurably greater, of vital importance, one affecting health and life, for, in the absence of phosphates, no bony frames can be formed to cover with muscles and endow with vital force; and one of the limits which bound the existence of man and the lower animals is the quantity of phosphoric acid which can be made available and used as a vital "circulating medium."

I need not dilate upon the importance of a large and practically exhaustless source of phosphoric acid, especially so long as our municipal authorities continue to make use of our streams as convenient conveyances to deposit our supplies of phosphates in the sea, instead of using the sewage to re-fertilize the soil which has been exhausted in the production of food. Seeing this waste (which is nothing less than criminal) one would imagine that we did not expect to be followed by future generations, or else that some one had invented some improvement on the

* Read before the British Association, Liverpool Meeting, Section B.

work of the Omnipotent, and the framework of the bodies of future generations were to be built up without the use of phosphates at all. By proper utilization and conservation of the elements of food, whether in the form of excretal matters or of mineral substances, it is possible that to make "every rood of ground maintain its man" may be not only the aspiration of a poet, but a matter of sober fact.

As an illustration of the quantity of phosphorus which is present in the iron made in Great Britain, I may point to Cleveland, which manufactures 1½ millions of tons of iron per annum. This iron, at the low estimate of 1¼ per cent., contains 18.750 tons of phosphorus, which is equal to 42.943 tons of phosphoric acid. This phosphoric acid is sufficient to supply the phosphoric constituents to 3,400,000 tons of wheat. In the absence of strict statistics on the subject, it is not too much to assume that, in the whole of the British iron manufacture, this quantity might be tripled, with every confidence that it is considerably under rather than over the fact.

When phosphoric pig-iron is converted into malleable iron, the phosphorus is, in great part, transferred to the refinery and puddling furnace cinder in the form of phosphate of iron. The quantity of phosphoric acid varies of course with the composition of the pig-iron from which it is contained. The cinder produced from refining and puddling Cleveland pig contains generally from 3 to 7 per cent. of phosphoric acid, which is from one-fourth to one-half the phosphoric acid present in good commercial soluble phosphate of lime. This cinder is sometimes again used for the manufacture of pig-iron, but the product is, on account of the accumulation of phosphorus, of small commercial value, while, if the phosphoric acid were previously separated, it would be capable of yielding iron quite equal to that produced from hematite, or could be again used for "fettling" puddling furnaces.

While at this part of the subject I may refer to the contradictory and incoherent theories given to account for the separation of phosphorus from the iron and its transference to the cinder while being converted into malleable iron by the ordinary refining and puddling processes, while in the Bessemer process the amount of phosphorus separated is very small. I could get no satisfactory explanation from other sources, and, therefore, made these reactions a subject of study and experiment for over three years, and I gave the results in a paper read before the Liverpool Polytechnic Society. To repeat this would extend this paper to too great length, and I must refer those who take an interest in the subject to the "Journal" of the Society for May, 1869.

The concentration of the phosphorus from the pig into the cinder in the form of phosphate of iron renders it more easy and practicable to separate when the preparation of compounds of phosphoric acid is the object in view, as there is a smaller bulk of material to be treated to obtain a given amount of product.

The phosphoric acid may be separated either in the form of soluble superphosphates of lime and magnesia or of the alkaline tribasic phosphates. To effect the former the cinder is melted with lime and magnesia; and to do this it is best to either use lime in the furnace during puddling, or else add it at the end of the operation before the cinder is run out, so as to save the fuel required to re-melt it. This is then roasted in the ordinary way of making what is technically called "bulldog." By this roasting the protoxide of iron is converted into magnetic oxide or into peroxide of iron, both of which are very slowly soluble in cold dilute hydrochloric acid, while the phosphate of lime is readily dissolved out, leaving the oxide of iron and silica behind. Or, instead of fusing the cinder with lime, it is first dissolved in hydrochloric acid, the silica being left behind insoluble, except a small proportion of gelatinous silica; sufficient lime or chloride of calcium is added to saturate the whole of the phosphoric acid present in the cinder. The chloride of iron is then concentrated to dryness. If in an open reverberatory furnace and in an atmosphere containing water vapor, hydrochloric acid is again liberated, which can be condensed and used again to dissolve more cinder. The peroxide of iron is then heated to redness to render it insoluble, and cold dilute hydrochloric acid added, which dissolves out the phosphate of lime, leaving the oxide of iron nearly pure. If it is desirable to obtain the chlorine in its isolated state instead of in the form of hydrochloric acid, the chloride

of iron is dried in a close vessel, and dry atmospheric air passed through it at a temperature about the melting-point of zinc; the chlorine is liberated and peroxide of iron formed. The manufacture of chloride of lime or bleaching-powder can, therefore, be economically carried on in connection with the manufacture of phosphates and pure iron oxide, dispensing with the use of manganese, and with the further advantage that a given amount of hydrochloric acid will produce double the amount of chlorine that can be produced by the use of manganese. To obtain phosphate of soda, I keep the cinder free from lime and grind it to a powder, then I add a solution of caustic soda in good excess, so as to separate the whole of the phosphoric acid from the cinder before throwing the cinder out, and add the solution of phosphate and excess of caustic soda from that to an excess of cinder, so as to convert the whole of the caustic soda into phosphate. The partially exhausted cinder is then again treated with an excess of caustic soda to separate the whole of the phosphoric acid. The diphosphated cinder still contains the silica originally present, and it seems to combine with some of the soda used to dissolve out the phosphoric acid, as there is often 20 per cent. of the soda used remaining in the cinder. This cinder may be again used to fettle puddling furnaces, and the soda present in it cannot but facilitate the transformation of the phosphorus in the pig into phosphoric acid in the cinder; the presence of the silica, however, is objectionable, on account of its neutralizing a great proportion of the bases present in the cinder. It is desirable that the cinder produced from the fettling and the iron together should be as free as possible from anything which can saturate the basic material, so as to allow of a greater amount of free base, which readily facilitates the formation of phosphate of iron. To allow of this when making phosphate of soda, I dissolve the cinder the same as before mentioned, leaving the insoluble silica behind. The chloride of iron is then dried and used in the production of chlorine, or the hydrochloric acid may be again recovered to use over again. The oxide of iron, *plus* phosphate of iron obtained after the separation of the chlorine, is then treated with caustic soda to obtain solution of phosphate of soda, the practically pure oxide of iron remaining insoluble. The phosphoric acid in the iron ores exists principally as phosphate of lime, which, in fact, is the remains of extinct animals. To separate the phosphate, the ore is roasted so as to render the oxide of iron insoluble. The ore is broken into suitable sized pieces, say about 2 in. cube, and cold dilute hydrochloric acid run through it, which takes up the phosphate into solution, leaving the oxide behind.

The limit to the manufacture of the acid phosphate is, practically, the quantity of hydrochloric acid which is produced in the manufacture of sulphate of soda, over and above what is required for the manufacture of bleaching-powder and a few other purposes. The exact quantity of this acid I have not had time to ascertain with any degree of accuracy, but in the alkali works on the Mersey, and it is much the same in other places, there are literally brooks of hydrochloric acid run to waste; besides, the fact that the acid at present used in the manufacture of bleaching-powder can, by the use of chloride of iron process, be reduced to $\frac{1}{2}$, and, in many cases, to less than $\frac{1}{3}$, its present quantity, will liberate a still further supply of acid to be used in the preparation of acid phosphates. There is here an opening for the consumption of a great amount of valuable material which is at present run to waste. There is, of course, no practical limit to the further production of hydrochloric acid, whatever may be the quantity required, if a rise in price should occur sufficient to justify its special manufacture, and the manufacture of phosphate of soda is also unrestricted so far as supplies of soda are concerned.

The only objection to the use of such hydrochloric acid as is produced in the course of the alkali manufacture, is the presence of arsenic. This, however, is practically a small difficulty, the same person who produces the hydrochloric acid also produces sulphide of calcium in the shape of alkali waste. A current of sulphide of hydrogen (which can easily be produced from the waste) passed through the acid readily precipitates the arsenic in the form of orpiment, for which there is a regular demand at remunerative prices. The separation of the arsenic will, if fairly attempted, more than pay for the cost of obtaining it.

ROLLING LOADS.

From "Engineering."

In the present day, excepting only Government wagons, rude agricultural carts, and wheelbarrows, everything running upon wheels is seated upon springs. This fact is a practical acknowledgment of the essential difference between a moving and a stationary load. When a vehicle is at rest the deflections of the springs are constant, and afford as exact a measurement of the insistent load as could be obtained by taking the wheels over a weigh bridge. If the load continued to press with the same intensity upon the wheels when in motion springs would be useless, as their deflection would remain unaltered, and a solid block might, consequently, do their work. But experience has taught us that on the smoothest railroad the springs are at once sensitive to the slightest movement, and that they may be advantageously introduced, and come freely into play, even in the instance of the slowly-revolving turned rollers travelling on the accurately-faced roller-path of a large swing bridge. The deflection of the springs of a vehicle in motion is alternately greater and less than the mean deflection when at rest, and the irresistible inference is that the wheel will press upon the supporting medium with a maximum intensity corresponding to the greatest deflection of the spring. No better opportunity of appreciating the practical effect of this condition could be obtained than is afforded by the running of a couple of trains at high speed in parallel lines and in the same direction. The observer in one train can then note the movement of the springs, with the horizontal element eliminated and the vertical alone apparent. It is hardly possible under these circumstances to avoid drawing a parallel between the train and a ship in a moderately smooth sea. The rising and falling of the several springs correspond with that of the waves, the mean deflection and the mean line of flotation is the same, respectively, as when the train is at rest and the ship in perfectly smooth water; but the maximum stresses must be deduced from the maximum deflection of the springs in the one case, and from the immersion measured from the crest of the waves in the other; a very long railway carriage with a large number of wheels would have no vertical movement itself, neither would a very long ship. Expanding this deduction, we are led to the conclusion that a long-span bridge will suffer no increase of strain from the varying deflections of the springs induced by the unavoidable deviations from mathematical accuracy in the levels of the permanent way, although the rails themselves may be subject to strains some 30 per cent. greater than those due to the load at rest.

There may, however, be some other agency at work increasing the strains under a rolling load beyond that evidenced to the senses by the springs; and, as this is a question of paramount importance in the economic design of railway bridges, it is no matter for surprise that it has engaged the attention of the most eminent mathematicians and experimentalists. The results of the earlier experiments on the influence of rolling loads were certainly very alarming, as they appeared to indicate that one ton moving at 30 miles an hour was as destructive to a beam as $2\frac{1}{2}$ tons at rest. Observations of the deflections of actual bridges, however, soon reassured engineers, as the deflections under speeds of even 40 or 50 miles per hour were not practically greater than those due to the same load at rest. Theoretical considerations, at first sight, might erroneously lead us to anticipate a greatly increased deflection under a rolling load, since they indicate the maximum deflection of an elastic beam under a suddenly imposed load to be double that of the final deflection after oscillations have ceased. The reason for this is obvious enough, for the work done by the beam must be equal to that done by the load, and as the latter is equal to the product of the load into the ultimate deflection, the former must be equal to the product of the mean resistance of the beam into the same deflection; hence the *mean* resistance of the beam must be equal to the load, and as the resistance is *nil* at the commencement of the bending, it must be equal to double the load at the termination.

But the conditions of the rolling load

on a railway bridge are not analogous. The load is not sufficiently suddenly applied, and the horizontal motion and *vis viva* of the train destroys other conditions. It might at first be concluded that at least the cross girders of a bridge spaced at intervals of a yard only, and where consequently at 60 miles per hour the load would be imposed in the thirtieth part of a second, would constitute a case of suddenly imposed load and double strain, but experience does not bear out this conclusion. In an instance observed by the writer the deflection of some 8 in. cross girders, amounting to $\frac{3}{8}$ths of an in. under the driving wheels of the engine when at rest, was increased to $\frac{1}{2}$ in. only when the engine traversed the bridge at considerable speed. In fact, in this case it was evident that the work done in deflecting the several girders was not performed, as in the case of a suddenly applied load, by a *vertical* descent of the weight at each girder, but by increased *horizontal* traction on the whole train; in the same manner as the wheel of a road vehicle passing over soft ground consolidates its path by the formation of a rut, at the expense of an additional pull, and not by an up-and-down hammering of the wheel.

One element of increased strain on the main girders of a railway bridge under a moving load is sufficiently apparent, but on investigation turns out to be insignificant in effect. The rails, if normally horizontal, will obviously be deflected below the horizontal line when the load is traversing the bridge, and the path of wheels therefore will be approximately an arc of a circle. The resulting centrifugal force will take effect upon the girder in a practically vertical direction, and in terms of the load the increased bending stress will, of course, be equal to the square of the velocity in feet per second, divided by 32 times the radius of the deflective curve in feet. In practical cases this increase, as we have before observed, will be found insignificant.

The most recent researches of mathematicians show that the passage of a train of ordinary length does not afford sufficient time for the attainment of molecular equilibrium in the girder, and that the increase of strain is not worthy of note. M. Bresse has shown that with a train of indefinite length, moving at the highest practical velocity, the strain, neglecting the effects of possible concussion, may be one-third greater than that due to the same load at rest; but that if the initial camber of the rails be four-thirds of the statical deflection, this increase, under the same reservation, will not take effect.

It is apparent, therefore, that if any important modifications are required in girders subject to a rolling load, it can only be to provide against the effects of shocks arising from irregularities in the roads and other similar causes. The interposition of springs protects the ironwork from direct impact, or some difficulties would be encountered in dealing with the light cross girders of railway bridges. Experiments on the effect of falling weights give very conflicting, and in some instances, unintelligible results. We can easily understand that a rectangular bar of any proportions, provided it be of the given weight per foot, will stand the same intensity of blow, whether it take effect on the flat side or on the edge of the bar; because the work done in fracturing the bar will be proportional to the product of the breaking weight into the ultimate deflection, which will be a constant amount for all rectangular bars of a given span and weight per foot. It is not so apparent, however, that a round bar of the same weight per foot will sustain the same blow as the rectangular bar, nor that the deflection will be proportional to the velocity of impact instead of the square of the same, yet both these are deduced facts from experiment.

The general tenor of the evidence gradually accumulated by engineers relative to the effect of moving loads tends to prove that no additional strength is on that account required in the main girders of railway bridges above some 20 ft. in span, provided the permanent way be kept in fair order, but that the cross girders should be calculated to sustain the load corresponding to the maximum deflection of the springs, which will ordinarily be some 25 per cent. greater than the normal load. There are no grounds for the adoption of a factor of safety of ten in railway practice where moving loads are concerned, as urged by some writers, although that factor is quite justifiable in the instance of machinery, where genuine sudden strains have to be encountered.

ON LIQUID OR CONCENTRATED FUEL.*

By Captain J. H. SELWYN, R. N.

From "Engineering."

In continuing the subject of liquid fuel before the Institution of Naval Architects this year, I wish to draw attention specially, to the value of the principle of concentration, which is involved in the use of such a combustible.

I have, therefore, headed the paper with a double title, of which one part refers to the liquid condition of the fuel, the other to the fact of its being highly concentrated. In order to understand what is the importance of this lat er fact, we have only to consider how seriously we should be inconvenienced in our use of fuel if nature had not supplied us with large stores of what was no doubt originally vegetable substance, but is now condensed into the form of coal. So long as forests of great size admit of our resorting to them for our supplies of fuel, they are sufficient for the wants of mankind, at least in their immediate neighborhood; but their use becomes too expensive so soon as distant transport is an element of the question. As for steam navigation, no fuel in a less condensed state than that of coal could possibly be used largely for long voyages.

But we have certainly not yet come to the end of what may be useful concentration of our heat-producing agents, and I am about to draw your attention anew to the way in which this may be done and the advantages of doing it.

Since I last addressed the Institution on this subject I have continued the experiments on which I was then engaged at Woolwich up to the time at which the closing of that yard put a stop to them; I hope to see them resumed, and carried to a legitimate conclusion, but I cannot go to much expense myself, and so little is now allowed to be expended even on the most useful experiments by the Government, that it is extremely doubtful when the authorities will consent to do what would inevitably save many thousands of pounds to the nation, were it done. In order to convince you that I am not overstating the economy to be expected and the convenience that may result from the further experiments which I advocate, I will now, after a short recapitulation, place before you the facts on which I ground such an opinion.

I showed in my last paper that the chemical analysis of the oil used entitled us to expect that its theoretical calorific value, that is the number of pounds of water 1 lb. of the oil I used might theoretically be expected to evaporate, would be 17.5. I also showed that in a trial at Woolwich in the Oberon boiler, in which economy was the sole object and quantity was ignored for the time, 16.9 lbs. of water were evaporated, and although the quantity in a boiler of 1,702 sq. ft. of heating surface was then only about 60 cubic ft. per hour, I assured you that this was only because no more oil could be burned in that trial on account of an insufficient supply of steam from the small boiler which served the injectors. The trials were continued with such alterations as were found to be most productive of good results from April to July, 1869, and at the latter date we had succeeded by a gradual amelioration, and by taking the steam for jets from the large boiler itself, in increasing the quantity to 236 cubic feet per hour, with an economy of 14.9 *both after* deduction of the water or steam used in the jets. But at this point of my observations I must entirely refuse to concur in the propriety of any such deduction being made, and this for two reasons. First, because from the experiments of Bunsen and Fyfe, names which command the highest confidence among chemists of all nations, it appears, that red hot coal and "aqueous vapor mutually decompose each other into hydrogen and carbonic oxide gases with some carbonic acid, both of which, if sufficient oxygen be present, burn with the production of a white heat, to form water and carbonic acid, and that numerous observations showed further that the additional heat evolved *more than compensated* for the fuel used in producing the vapor." Secondly, because, as you will see from the tabulated form, which is official (except where special figures are shown) at a time when 16.1 lbs. of water were being evaporated by the use of each

* Paper read before the Institute of Naval Architects.

pound of oil (the theoretic calorific value being 17.5) the temperature of the chimney or that of the escaping gases was 680 deg. Fahr. Now according to one of Professor Macquorn Rankine's formulæ, which runs thus :

$$\text{Loss up chimney} = \frac{1+A \times T \cdot C}{40.0 \text{ Fahr.}}$$

1+A is here 16.3 the weight of burnt gas, and T.C is temperature of chimney. Then 680 deg. Fahr. corresponds to a loss of 2.7 units of heat or pounds of water vaporizable. Now deducting the evaporation actually obtained, namely, 16.1 from 17.5, the theoretic ultimate calorific effect of the oil, we have 1.4 which might possibly be due to the oil. But how shall we account for the other 1.3 of heat in the escaping gases, unless we allow that this is a corroboration of Bunsen and Fyfe's observations, and that consequently the water used in jets ought not to be deducted from the total evaporation of water from the constant of 212 deg. feed.

At any rate I think it fair to show you what would be the results if this be the right view, and you see the special figures showing 254 cubic ft. evaporated per hr. at the rate of 16.18 lb. for every pound of fuel consumed. As this is done with a boiler whose total heating surface is 1702 sq. ft., it amounts to a cubic ft. of water evaporated per 6.7 sq. ft. of heating surface with an ordinary tubular marine boiler situated on a cold wharf, and only partially lagged or covered with felt. This duty was performed by the boiler with the ordinary arrangements of firebars, ashpit, and firedoors, and there was nothing to prevent coal from being burned the next hr., or at the same time if desired. The experiments with the firebrick combustion chambers, built in the ashpit, did not turn out to be superior in results to those arranged as above, and as such an arrangement necessitates the use of a small auxiliary boiler to raise steam in any moderate time, they were discontinued. This, however, might not be the case with a different type of boiler. I am of opinion that the results above described might yet be beaten in the same boiler if a higher class of oil and more steam were used ; but as it was, I was obliged to be careful, since even with a large steam pipe open, besides the jets, the safety valves were not always able to prevent the pressure rising beyond the 24 lbs. at which we were working. It was, of course, necessary then to shut off some of the oil, which is done by a mere touch It will be remembered that, while with coal no more than a certain number of pounds can be placed on the grate so as to burn, there is no other limit to the quantity of oil that may be burnt than the supply of steam to the injectors, or in a short boiler the loss of heat up the funnel.

As regards safety, there is no longer the slightest doubt on the minds of those who use this fuel. The oil only differs from ordinary train oil in this particular, for the reason that train oil would float on, but this oil sinks under, salt water ; it is therefore less liable to accidental combustion, and more easily put out, should it ever inflame when substances are thrown into it that may act as wicks. A white hot firebrick may be plunged into the oil with the most perfect impunity. If shavings are thrown in and set on fire, these form wicks, and the oil burns as train oil would do, but water will instantly extinguish even this. In short, I confidently state that all idea of danger may be dismissed at once and for ever with an oil whose specific gravity is 1050 and upwards.

I can only account for its not having already come into general use as fuel by three considerations. First, the prejudices which invariably retard new applications of knowledge. Secondly, the attempts of holders to realize high prices before the economies derivable have become fully known ; and thirdly, because several persons have thought they could do without those who had studied the question, and have, therefore, only succeeded in burning the oil wastefully.

I am satisfied that there is an ample supply of material from which the oil can be obtained at a remunerative price, that shipowners can well afford to give from £2 to £3 a ton for it when they know its use thoroughly, and that it is at this moment cheap to use it at the 30s. per ton of 213 gallons which is asked for it, seeing that if 1 ton of it used without stoking, be it remembered, is equal to 2 tons of coal in evaporative duty, if that ton only takes 36 cubic ft. of space instead of 92, which 2 tons of coal would occupy; if again every drop of the oil does its work, while there is a large proportion of ashes and slag in the coal ; if, I say, these and other economies, not so apparent, but still im

No. of Trial.	10
Date of Trial.	July 1, 1869
Time.	
Lighting up in the Small Boiler.	a. m. 8.0
Steam up to 20 lb. Pressure.	a. m. 9.05
Occupied.	h. m. 1.05
Lighting up in the Trial Boiler.	a. m. 9.25
Steam up to 15 lb. Pressure.	a. m. 10 15
Occupied.	h. m. 0.50
Coal Consumed in Raising Steam Small in Boilers.	lb. 160
Fuel Consumed in Raising Steam in Trial Boilers.	lb. 610 coal, 120 oil. 730 total.
Time.	
Commencing the Experiment.	P. m. 12.40
Ending the Experiment.	P. m. 5.02
Occupied on the Experiment.	h. m. 4.22
Temperatures.	
Water in the Boiler on Lighting the Fires.	Fah. 144°
Feed Water.	Fah. 62°
Atmosphere.	Fah. 70°
Bottom of Funnel.	Lead melts
Mean Pressure of Steam.	lb. 24
Weights.	
Oil Consumed during the Experiment.	lb. 4312
Water Evaporated during the Experiment.	lb 5506

Oberon Boiler, Tubular Marine Heating Surface in Tubes 1468 Square Feet in Furnace, and Uptake, 234 Square Feet; Total, 1702 Square Feet.

Water Evaporated to 1 lb. of Oil Consumed.	
At the Actual Temperature of the Feed Water.	lb. 13.70
At the Constant Temperature of 100° Feed Water.	lb. 14 11
At the Actual Temperature of Feed Water after Deducting the Water Used for the Jets.	lb. 12.70
At the Constant Temperature of 100° Feed Water after Deducting the Water Used for the Jets.	lb. 13.11
After Deducting Water Used for Jets at the Constant Temperature of 212° Fahr.	lb. 14.98
Without Deducting Water Used in Jets from Constant Temperature of Feed 212° Fahr.	lb. 16.16
Heating Surface per Cubic Foot of Water Evaporated per Hour at Constant Temperature of 100° Fahr.	sq. ft. 7.65
Oil Consumed per Hour.	lb. 989.00

Water Evaporated per Hour.	
At the Actual Temperature of Feed after Deducting Water Used for Jets.	cub. ft. 200.08
At the Actual Temperature of Feed without Deduction.	cub. ft. 215.90
From the Constant Feed of 100° Fahr. without Deduction.	cub. ft. 222.39
From the Constant Feed of 10 ° Fahr. after Deduction of Water Used for Jets.	cub. ft. 208.08
From the Constant Feed of 212° Fahr. without Deduction.	cub. ft. 254.76
From the Constant Feed of 212° Fahr. after Deduction of Water Used for Jets.	cub. ft. 235.09

Approximate Amount of Water Evaporated for the Use of the Steam Jets.	During the Experiment.	Per Hour.	
	lb. 4312	lb. 989.00	cub. ft. 15.82
	cub. ft. 69.68	cub. ft. 969.00	

portant, are to be considered as they deserve, then no long time ought to elapse before it is brought into use in our commercial marine.

But of course I am more especially anxious that our navy should profit by it, and what I now desire is, that having proved so much in a steam launch first, and then in an ordinary marine boiler on the wharf, the next step should be taken of fitting it in a gun vessel of moderate size, whose performance is already, known well in order to test it fairly at sea, and to estimate accurately what may be the subsidiary economies that attends its use there, in order to know what price can be given for larger quantities when required. Then the condensation of which I spoke will take place as an ordinary fulfilment of the law of supply and demand, the light spirits, and other products including illuminating oils, will find their proper market, and the distiller of such will no longer consider so large a proportion of his distilled products as mere waste unsalable at any price. This was, I am informed, the case at Wareham, near Poole, where the distillation of shale (forming cliffs along that coast) was once carried on with a result of 50 gallons of crude oil to the ton of shale, or Kimmeridge clay.

This distillation was voted a nuisance by the inhabitants, as it was attended by a very disagreeable smell, which was, however, solely due to the fact that the distillers did not then provide means of burning these gases under the stills, as they might, and ought to, have done with considerably increased economy in the production. I believe the process established at Chatham by Messrs. Dorsett and Blythe for heating armor plates, etc., by liquid fuel, is still carried on there with admirable results. Mr. Barnes, of Victoria-park, also continues to speak highly of the apparatus of Messrs. Wise, Field, and Aydon fitted to his steam boiler, and I know that some mercantile men are anxious to fit it in their steamships as soon as practicable.

It is essential to the proper burning of this oil that it should not, while entering into combustion, be cooled down in any way, and a mass of fire-brick, slag, or other rough material on the fire-bars, forms a very good heat governor, but the ashpits and firedoors ordinarily fitted are decidedly not the best that we could have. Some flame (as a piece of lighted wood or cotton waste) should always be in the furnace when turning the oil on. The existing form of injector can scarcely be improved on, excepting in very large furnaces, where they ought to be double. In some cases the oil may be sucked up from tanks placed below the boilers, by the steam that burns it. The higher the pressure and the drier the steam the better. Superheated steam is always preferable; for the jets and this should be made in the chimney where the heat passing off is otherwise clear waste. Joints for the oil should be made with lime and glue; no red lead joint is of any use. As little water as possible should be allowed to mix with the oil, otherwise the fires are soon put out, though the water will always keep at the top of the oil unless much agitated.

The raising of steam in all these last experiments was done as in an ordinary coal boiler, and the steam, when raised, was taken to the injectors from the large boiler itself. No sweeping of tubes or clearing of fires was ever necessary from November, 1868, to July, 1869.

I have now only to draw your attention to the tabulated results, and to request you to recollect my statement of last year, that the mean obtained with the boiler on trial in a stoke hole whose temperature was 95 deg. Fahr., with best steam navigation coal, were 8.2 lbs. of water evaporated per 1 lb. of fuel and 200 cubic feet of water per hour, both calculated from the constant of 100 ft., which I do not approve, as it takes no account of the latent heat, and does not give any real estimate of calorific power comparable with the chemical analysis of the fuel experimented with. I have now fulfilled the promise of further information made by me at your last session; and while I feel grateful to the Admiralty for enabling me to carry on the experiments so far, and to those who have contributed in various ways to take a portion of the burden of them from my shoulders, I feel also that it is my duty not to relax my efforts to get the investigation continued, and still more light thrown on the question, and in the hope that I shall succeed in these efforts, I renew my promise, if all be well, of another communication in continuation of the same subject for the session of 1871.

SEA WALLS AND FORESHORES.

From "The Engineer."

The heavy gales which at times rage about our coasts occasion very great damage to the sea walls and paved foreshores of the kingdom. Immense is the first cost of these gigantic works, extending continuously in many places for 10 or 15 miles, and tens of thousands of pounds are spent annually in repairing them; the reason of the continued destruction of such works being that the sea obtains access under or through the interstices of the sea walls or long sloping foreshores, and either undermines, or, by hydrostatic action, forces the stones out of place. Vast destruction of property at times ensues, and, indeed, whole districts are occasionally laid under water by such inroads of the sea. The difficulty encountered in forming foreshores of a permanent character consists in the absence of a cement which should have the property of hardening rapidly in water, combined with durability. It is found that the interval of a tide is not enough to enable the best cements in use to harden before the returning tide or sea, which, when strong, displaces the cement partially or wholly; but when, through fortunate circumstances, it is enabled to set, the sand and gravel dashed against the wall in heavy gales tears and abrades it away in a year or two, and the danger and expense are again incurred. Some years since, Captain Cochrane, R. N., of the Junior United Service Club, induced Mr. Elliott, the engineer superintending Dymchurch wall, to try a cement made from bitumen found in one of his estates in Trinidad, one ton of which, mixed with about nine tons of gravel and a little gas tar and lime, forms an extremely cheap material admirably adapted for the purpose of cementing sea walls. Captain A. Cochrane has favored us with the following copies of Mr. Elliott's report, which will be found extremely interesting to engineers. Experiments go to show that the tenacity with which bituminous cement adheres to stones, iron, bricks, or wood, and the rapidity with which it sets is so great, that when once joined, and the material broken with a hammer, the fracture is generally through the bricks or stone, in preference to the adhering film of cement.

Mr. Elliott, writing from Dymchurch, 24th March, 1860, to Captain Cochrane, says:—

"Sir,—The time has now arrived when a decided opinion may be given on the merits of the 'bitumen' you sent me for experiment on the sea wall at Dymchurch. It may, perhaps, be well for me to state that the slope of the sea wall lies on an inclination of about seven to one, faced with Kentish ragstones in large irregular blocks, very roughly dressed, having considerable interstices to be filled with the sand and shingle constantly passing over it. With an off-shore wind from N. E. to W. there is no difficulty in keeping these interstices full, and when this is so, but little damage ever occurs, although a heavy sea from ground swell may be falling on the face of the wall. With an on-shore wind from S. W. by S. to N. E. by E. the very reverse of this takes place, the whole of the sand and shingle is washed out of the joints, the paving becomes loose, and frequently breaks up to a large extent. Seeing all this occurring from year to year, I have, for many years, been anxiously looking out for some material that would stand the wear and tear of the sea (mixed up, as it is, in every gale with a mass of sand and shingle), easy of application, so as to prevent the sand and shingle being washed out of the lower portion of the joints of the paving. No cement that I have yet tried—and I have tried various—will stand the heavy surf and scouring for more than a week or two. Owing to the lateness of the season, 1858, when I received the bitumen from you, I was unable satisfactorily to cover but a very small space of the stone paving from the difficulty in getting the stonework sufficiently dry during the ebb of the tide. However, I was very anxious to see the results of this (to me) new material; so, with a little perseverance, I got about 500 sq. yds. of the stonework pointed up; that is, I had the joints of the stonework picked out as deep as we could, and then filled with the bitumen, mixed in the proportions you advised it to be used. The result of this small experiment was, to my mind, very satisfactory. I found it soon set firm, and adhered well to the stones,

a point which I had some fears about when using it, as we could not at that season of the year [November and December] get the stones to dry as I could have wished, and as we could have easily done in the summer time. This portion after sixteen months' trial, remains, to all appearance, as it was on the day it was put down, only a very few portions having been washed off, and these very evidently where water had collected in the hollows of the stonework, and proper care had not been taken to dislodge it before filling up with bitumen. The incessant scouring of the sand and shingle for sixteen months seems to have had but little effect on it, while the very best cements, both Roman and Portland—in various states of combination with shingle, gravel, and pouzzolana—have invariably been scoured off and utterly gone in a few weeks. In the spring of 1859 I used up all the bitumen I had remaining, which enabled me to point up in the same way as that done in the previous autumn about 1500 sq. yds., in addition to the 500 then down. In this I have taken some liberties with the proportions of bitumen, lime, gravel, and tar that you furnished me with; it appeared very evident to me that the bitumen, without any loss to its properties of cementing, would take a much larger proportion of clean shingle and gravel. I increased this proportion until I had doubled the quantity of gravel, that is twelve to one instead of six to one, I also omitted the oil of tar, using in lieu of it a double quantity of gas tar. I am of opinion that for the purposes we required in filling in the large interstices of the tone-work, the proportion of clean shingle or gravel could be still further increased, thus very materially diminishing the cost, a very material question in the immense surface we should have to cover. In addition to the 2,000 yds. 'pointed up' I selected a space of about 200 yds. of the very worst portion of the wall, that is where the stone paving was most worn and open, my object being to bring this rough and open surface to as smooth and even a face as possible; to do this in many laces the bitumen would be 6 in. or 7 in. n depth, in these large places. While he bitumen was in a plastic state I forced into the mass as much as I could of broken pieces of stone, Kentish rag, somewhat larger than would be used for road repairs; these at once set firmly, and altogether made the most satisfactory work. The whole of this 2,200 yds. was selected on the slope of the wall between high-water spring tides and high-water neap tides—so that every tide washed over it more or less. I selected this position because it is there where we invariably get most damage, and it is there in particular where we require better protection than we have hitherto been able to get. What I have done has now passed through, first, one of the hottest summers we have had for many years; and, secondly, it has also passed through by far the most severe winter, for storms, cold, and wet, that I have ever experienced, and I have had constant charge of this sea wall for more than twenty years. Five months, and not one week without a gale of wind; nearly 40,000 yds. of the stone paving on the wall has been broken up, but not one yard where the bitumen had been employed. It has been broken up above and below it, and on either side, thus giving, in my opinion, the most conclusive proof of what inestimable value this material would be in so extensive and important a work. Neither cold nor heat affects it in the least, as far as durability is concerned; a very hot sun softens the bitumen to some little extent, but this in my opinion is an advantage rather than otherwise, as this softening tends effectually to fill in any vacant space that may exist in the stonework, and thus thoroughly adapts itself to the irregularities of the stone-work, the surface being rendered hard the moment the flowing sea reaches it, and then no amount of friction seems to have any effect on it. I found the cost of applying the bitumen, as I have stated above, to be as follows:—The 500 yds. done in November and December, 1858, cost 7½d. per yard; the 1,500 yds. done in the spring of 1859, 4½d. per yard; and the 200 yds. 18d. per yard. This is calculating the bitumen at £4 10s. the ton. I consider the last portion of 200 yds., at a cost of 18d. per yard, to be in every way the most satisfactory. I cannot conclude this report without thanking you most cordially for your great liberality and kindness in placing me in a position to carry out these experiments almost free of cost. Important as the question may be, it is well known that it is no easy matter to induce non-scientific men to incur expense in experiments—with what to them may be a novelty—and

the results of which may be doubtful. Thanks to your liberality, I have avoided this difficulty, and with the self-evident fact before us, I hope at no distant day to induce the authorities having charge of this subject to carry these experiments to a much greater extent."

Mr. Elliott wrote again to Captain Cochrane from Dymchurch as follows :—

"DEAR SIR,—In the spring of 1860 I sent you a report on the results of the trial of a few tons of bitumen I had used on the sea wall at this place during the two previous years. At the end of ten years it will, I have no doubt, be interesting to you to learn what I can now report on the matter. By referring to my previous report you will find that I pointed up about 2,000 sq. yds. of the stone paving, forming the long seaward slope of the sea wall, that is, all the sand and shingle in the joints of the stone paving was picked out some 2 in. or 3 in. deep, and then filled in full with hot bitumen, so as to make a tolerably even surface to the work. This stood the wear and tear of the sea for about eight years, and showed but little or no change ; but in the winter of 1866-7 the whole mass was torn up, rocks, bitumen, and earth below going in one general wreck. If we had taken the precaution of securing the ends of the paving over which the bitumen had been used, this part would, I have no doubt, weathered the storm, as the breach in the paving began at some distance from where we had used the bitumen. Once there was an opening below it, there was soon a clean sweep of the whole rock paving in the neighborhood, the sea paying but small respect to the paving, or bitumen, or anything else in its way. You will find in my report (1860) that I had selected a space of about 200 yards, where I had used the bitumen in larger masses, that is, where the joints and angles of the rock paving were worn away to a very considerable extent. Of this 200 yards the weather we had in 1866-7 carried away about one-third in the same way as the other, from a general breach, the sea getting under paving and carrying it away in masses ; but about two-thirds of this 200 yards still remains, and to all appearance is now in the same state as on the day it was used ten years ago. You will have gathered from my previous report that in using the bitumen I had selected the most exposed portion of the wall, that is, on the paved slope of the stone-work between high-water spring tides and high-water neap tides, my object being to ascertain to what extent the bitumen would resist the heavy scouring process incessantly going on over the face of the rock paving. The result shows most conclusively that this heavy scouring process has much less effect on the bitumen than on the hard Kentish rag stone that we use for the paving on the face of the sea wall. From what I have seen of the almost imperishable nature of the bitumen, I should think that it would be invaluable for marine foundations, dock walls, piers of bridges, etc., one of the great advantages attending its use for marine works being that immediately after its application to the stones it sets firmly, so that the action of the next tide, even within the half-hour, produces no effect on it beyond increasing the firmness, causing the exposed surfaces to become quite indurated and yet tenacious, whereas Portland cement is constantly washed out immediately after its application, owing to the time it takes to set. This last feature of Portland cement is mostly shown in places affected by tides, or when bad weather supervenes ; and as the bitumen will take an enormous amount of gravel or other similar material without injury to its binding properties, the cost of the bitumen at anything like 70s. per ton would bear a strong contrast to the cost of Portland cement, while on the question of durability it scarcely admits of any comparison. I have used Portland cement on the sea wall to a considerable extent in the same way I used the bitumen ; the cost yard for yard for Portland cement was nearly double that of bitumen, and was all gone even in the most favorable positions, in a year or two ; not from a break up of the paving, but fairly scoured off and out of the joints of the stone paving, and gone. I should much like to have a few more tons of the bitumen. My idea is that it would be better to use it in a mass, to form a face by itself to protect the earth below ; but on this matter I will write to you again in a few weeks time.

A QUICKSILVER mine has been discovered in the district of Retiro, in the principal mountain range of Guija, State of Antioquia.

ON THE DUTY OF CORNISH AND OTHER PUMPING ENGINES.

From "The Artizan."

The differing features of the Cornish engine from other pumping engines are as follows :—1. It is generally worked at a high rate of expansion ; 2, there is a steam jacket attached to the cylinder ; the cylinder is covered with felt, and in addition to this, a covering of ashes or clay about 1 ft. thick, and then a covering of brickwork to prevent radiation, and there is a drain pipe from the jacket to carry away the water from the condensed steam to the boilers ; 3, the boilers and pipes are all arranged so that there is the least possible radiation of heat—the boilers being generally covered up with fine ashes or common clay. In three trials made with the engine to ascertain its duty, it was found that the effective duty varied from 4.4 lbs. per horse-power per hour to 5 lbs. When the balance-beam was attached and the arrangements completed, it was found that the effective duty was increased from 4.4 lbs. to 3.6 lbs., equal to a saving of 16 per cent., and which, taking the feed of water at 860 gals. per minute, would amount per annum to 420 lbs., and at 4s. per ton, to a saving of £80. Not only was there this saving, but also a steadier working of the engine.

The following table contains the results obtained in the work of 12 engines ; No. 1 being a Cornish engine :

No.	Dimensions of cylinder.	Gallons per minute.	Horse-power effective.	Effective duty in lbs. per horse-power per hour.	Indicated duty in lbs. per horse-power per hour.	Million lbs.	Cost per annum of coals per 100-horse power of effective duty.	Percentage effect.
1	70 in.	829	149.16	3.6	2.9	61.28	£283	81
2	77	1474	161.65	10.9	8.7	20 39	854	79
3	44	385	50 10	9 9	8.0	22.68	763	81
4	63½	1086	81.86	11.3	10.6	19.69	891	93
5	48	416	29.34	24.8	20.8	9 01	1940	83
6	82	191	69.29	28 5	—	7.78	2234	—
7	44	837	70.0	12.5	10.9	17.22	977	84
8	40⅜	785	71.36	16 9	13.9	13.05	1329	89
9	42	1469	98.03	10.6	—	—	849	84
10	52½	495	43.65	9.7	6.5	22 95	761	67
11	70	669	58 72	—	—	—	—	—
12	65½	324	54.16	27.4	—	6.27	2234	—

We find a total aggregate effective power of 1,030 horse-power applied, making an average duty of 14 lbs. per horse per hr. This we believe to be the average duty of the Newcastle district. Were a duty of 4 lbs. obtained, the saving in these engines alone would represent 40,000 tons of coal per annum, which, at 3s. per ton, would equal £6,000. We may safely assume the total horse-power of engines used for pumping water in the Newcastle district at about 10,000, and upon the above basis of saving we have a very momentous sum as the result. In many places coal may not be worth so much as 3s. per ton at the pit's mouth, but in the majority of cases it will very much exceed this.

We are too much inclined to think the coal at the colliery is of little or no value, and that the extra consumption of 10 lbs. or 12 lbs. per hour is not worth consideration. It must not, however, be forgotten that the fuel is not the only pecuniary part of the question, for additional consumption of coal means additional water, additional repairs, additional wear and tear, to say nothing of additional manual labor, and these in the aggregate are very serious items of cost. There is no doubt that more attention is being paid to these subjects than formerly, and we venture to predict that the time is not far distant when pumping and all other colliery engines will be erected with more regard to annual economy, and that the effective duty of 2 lbs. or 3 lbs. per horse power will be considered quite as important in them as it is now in London water works and in ocean steamships.

ON THE MODE OF WORKING COAL AND THE MECHANICAL APPLIANCES IN THE MIDLAND COAL-FIELDS.*

From "Engineering."

The author remarked in commencing, that one of the principal advantages of the practice of holding the annual meeting of the Institution in different localities was the opportunities which it afforded for the examination of the engineering features of the district, and particularly those in which the same end was accomplished by very different means. The last meeting was held in the northern coal-field, and much was seen of the modes of work there practised. The initial problem in all coal mining was the mode of dealing with the coal of the different strata which overlaid the seams and which imposed a statical pressure upon the new wrought seam in the ratio of its depth from the surface; this pressure being—roughly speaking—equal to about 1 lb. per square in. for each foot of such depth. There were two principles upon which this question could be dealt with, which when applied in practice might have very numerous modifications. In the early days of coal mining there did not appear to have been any intercourse between different mining districts, and it was somewhat remarkable, that whilst in some places the leading idea in the most ancient workings appeared to have been to work the coal in galleries and to support these by leaving pillars on either side of them, in many others the idea was to remove the coal entirely and to secure the necessary openings or working places along the edges of the solid seam by taking advantage of the resistance which the overlying rocks opposed to the vertical fracture in shearing. In some localities, therefore, methods of pillar work appeared to be indigenous, while in others the practice had always been to remove the whole of the coal at one operation, or, as it was commonly called, to work it "long-wall." This was the method of coal mining practised in the midland coal-fields, and the following is a brief description of the principles upon which it was based. In the actual working of a "long-wall" mine the first operation was to drive headways in the solid coal. When these had attained a sufficient length working places or stalls were started from the side of one of these, and the coal was removed in a series of slices parallel to the headway course. To support the roof of the working-places, timber was set, and a pack wall of lose stones was built up at regular intervals. As the faces advanced, the timber was withdrawn and the roof settled down—often without fracture—upon the packs. The roadways for the conveyance of the coal were carried at intervals of 20, 30, or 40 yds. between pairs of pack walls, and as the roof settled down and squeezed everything tight, the requisite height for the roadway was maintained by ripping or cutting up into the roof. The roadways, therefore, of a "long-wall" coal mine were carried through the goaf, or area where the coal had been wrought practically in the rock or other roof of the coal seam. As regarded the application of power for the underground haulage of coal, it seemed improbable that direct steam traction would ever be used except in a case where there was an arched roadway moderately level, and which could be provided with a distinct ventilation, a combination of circumstances that was not likely to occur often in practice. Attention might, therefore, be confined to stationary engines, driving ropes, or chains. Having referred to the method of hauling by "main tail" ropes, the author proceeded to consider the mechanical aspects of the question, and remark that in arranging any general system of underground haulage it was necessary to carry main roadways not merely on a level course, but with a rise or dip, or, indeed, in any direction which might be dictated by the position of the coal to be worked, in reference to the winding shafts. The average frictional resistance of wagon in collieries was given by the author as being $\frac{1}{30}$ of their weight, and it was stated that a falling gradient of 1 in 30 was sufficiently steep to enable full wagons when descending to overcome their own friction and haul up a train of empty wagons also. The author's remarks pointed to the conclusion that the haulage of *trains* of wagons in collieries was less advantageous in many

* Abstract of a paper read before the Institution of Mechanical Engineers, at Nottingham, on the 21 inst., by Mr. Geo. Fowler.

respects than the practice of attaching the wagons singly to an endless chain at intervals of 20 yds. or so. The endless chain would be driven by clip drums, and by this plan the wagons themselves would form rolling supports for the chain, and carry it without much additional friction. An application of this system in a mine in the neighborhood of Nottingham was described by the author, the chain in this case being merely allowed to rest in a kind of hook on the side of each wagon to be moved. The tendency to rust, caused by this side attachment, was stated to be counteracted by the tension on the rope, and it was pointed out that in this system the undulations of the road produced no effect so long as the series of wagons was continuous.

Proceeding to consider the lifting of the coal, the author next pointed out that although it is possible to balance accurately the weight of the ropes tubs, etc., yet the application of steam power to the raising of coal is not favorable to the realization of a high useful effect on account of the great weights which have to be brought into rapid motion, and subsequently into a state of rest. In deep shafts the weight of the ropes exceeds the net loads, and it is usual to balance them either by the use of a special drum and balance chain, or by coiling them on conical drums of such pitch that the moments of load with empty cages are at every portion of the engine approximately the same. The actual working of an engine consists therefore of a rapid series of motions in opposite directions. In raising a large tonnage of coal each journey of the cages is effected in less than a minute, and each time it is necessary to put the machinery in motion and stop it within that space of time. Three examples were given by the author, of different methods of working. Engine No. 1 was stated to be a vertical high-pressure engine with 40-in. cylinder and 5 ft. stroke, fitted with 12 ft. flat rope drum and small balance drum, the action of the balance being to assist the engine until the cages pass and to absorb power during the remainder of the run. Engines No. 2 are a pair of horizontal high-pressure engines with 36-in. cylinders and 6 ft. stroke fitted with round rope conical drums, the cone increasing from 20 ft. to 30 ft. in diameter. Engines No. 3 are a pair of horizontal engines of the same dimensions as No. 2, but with 14 ft. wrought-iron flat rope drums without counterbalance. In the case of engine No. 1, the engine man works with the throttle valve open, "hands" the engine fairly started, and then throws the valve gear into action, while at the end of the run he detaches the valve gear and meets the piston with steam on its opposite side. In No. 2 the engine man also works with an open throttle and regulates the engine by this link motion, reversing it at the end of the run; a steam brake being provided for use in case of need. In engine No. 3 the steam and exhaust valves are all worked by link motion and the engine is worked in full gear, the throttle valve being gradually closed towards the end of the run so that a partial vacuum is framed behind the piston, the engine remaining in forward gear.

In the cases above mentioned the loads are drawn from depths of 220, 470, and 415 yards in 30, 45, and 45 seconds respectively, the main speed of the cages being thus: 22, 27, and 27 ft. per second; but as about one-half of the revolutions are either accelerating or diminishing the velocity, the maximum speeds may be taken as 27, 36, and 36 ft. per second. The weight in motion may be estimated as follows:

	No. 1. tons.	No. 2. tons.	No. 3. tons.
Flywheel and drums	15	45	12
Ropes	4	6	7
Cages, coal, and tubs	6	4	8
Pulleys	2	6	3
	27	61	30

Some of the parts move faster, and others slower than the coal, but the mean speed of the whole may be taken as equal to that of the latter. Thus the power expended in putting the masses into motion at the velocities named, will be:

	No. 1.	No. 2.	No. 3.
Number of foot-pounds of work required	689,472	2,732,800	1,344,000
Time during which the above power has to be developed	½ min.	¾ min.	¾ min.
Equivalent effective horse power to be developed by engine	42 H. P.	110 H. P.	54 H. P.

The author then directed attention to the different modes in which the "work" accumulated in the moving mass was disposed of during the latter part of the "run" in the three cases under consideration, engine No. 2 pumping back steam

(drawn from a long exhaust pipe) back into the boiler. The author further pointed out that if the engine instead of having to develop at the commencement of each run a power greatly in excess of the average, had uniform or nearly uniform work to do throughout each lift, a much smaller engine could be used and there would be a saving of engine and boiler room effected. The question of economy of fuel the author regarded as being a secondary one in such cases. To attain the desired end of giving the engine approximately uniform work to do, the author recommended the employment of conical drums having their contour lines so far modified from those usually adopted that during the first two or three strokes of each run scarcely any lifting would be done, almost the whole power of the engine being employed in putting the machinery into motion. The contour, moreover, would be such that during the middle strokes the engine wi l lift the load and overcome the friction, and that in the last two or three strokes the leverage of the load will be so much increased that the momentum will be usefu'y expended in assisting the engine to complete the lift. In the apparatus which the author described in connection with this drum (which is in use in a colliery in the neighborhood), it was desirable for the purposes of ventilation to reduce the area of the cages, to avoid impeding the ventilation. So they were made with four platforms, each holding one ton of coal. To save time in emptying and loading, these platforms or decks were furnished with two points of unloading and loading, so that they could be all loaded and emptied with one change in the position of the cages. The time occupied is not more than twenty seconds, and the engine can raise 180 wagons of coal per hour.

EXPLOSIVE POWER OF NITRO-GLYCERINE.

From "The American Chemist."

A measure containing one cubic foot will hold 796 oz. of blasting powder, and 997.1 oz. of water; or, in other words, the specific gravity of blasting powder, as it is used, is about 0.8. This of course takes in the interstices, which are filled with air, but as we do not use the powder in a solid lump, this is, for practical purposes, the specific gravity of blasting powder. Now the specific gravity of nitro-glycerine is 1.6. Therefore, bulk for bulk, if the explosive power were the same in a given mass, as prepared for blasting, the nitro-glycerine would have twice the power.

In reality the following are the volumes of gas generated by each respectively in explosion:

One volume of powder which is considered as most effective, produces:

Carbonic acid gas	221.4 vols.
Nitrogen	74.6 vols.
Therefore 1 vol. becomes	296.0 vols.

Of another kind of powder, which explodes with the gases at a lower temperature, one volume produces:

Carbonic oxide	391 vols.
Nitrogen	66 vols.
One volume becomes	457 vols.

One volume of nitro-glycerine produces:

Carbonic acid gas	469 vols.
Water at 100° C	554 vols.
Oxygen	39 vols.
Nitrogen	236 vols.
One volume becomes	1,298 vols.

These volumes are given at 0 deg. C, in the case of water at the lowest temperature, at which it exists as a gas. Now for 1,000 deg. C. (which is supposed to be the temperature of the gunpowder gases at the instant of explosion), using the formula $V^1 = V(1 + t\,K)$, and taking K= 0.00366 and t=1,000 deg., these volumes will be about five times as great as those given above, *i. e.:*

1,480 for carbonic acid powder.

2,285 for the carbonic oxide powder.

If now we suppose the temperature of the explosion of nitro-glycerine to be 2000 deg. C, and make use of the same formula, we multiply the 554 volumes of water by $(1 \times 1900 \times .00366)$, since these volumes are given at 100 deg. C. We also multiply the remaining 744 volumes by $(1 + 2000 + .00366)$ and add the products together. The result shows the volume of the mixed gases to be about 10,607 times the original volume of the substance; and

as the specified gravity of the nitro-glycerine, as used, is twice that of the powder as used; or, in other words, in a given compass of nitro-glycerine there is twice as much explosive material as there is in the same volume of gunpowder, we may multiply this result by 2 to show the relative power, which brings this up to 21,214, or about 10 times as large a production of mixed gases for the nitro-glycerine as for the gunpowder which produces the mixed gases in largest amount.

Still 13 times is claimed by the advocates of nitro-glycerine. If this is so, the discrepancy between the temperature of the explosions must be greater than here assumed.

WORKING LOAD OF IRON STRUCTURES.

From "The Engineer."

The proportion which the working load of any cast or wrought-iron structure should bear to the load that would fracture it—usually termed its breaking weight—is a question upon which engineers are by no means unanimous. It is true that there is not that flagrant discrepancy now existing that prevailed many years ago, when the Royal Commission was appointed to inquire into the application of iron to railway purposes; but still the point remains practically as undecided as ever. At that time the two extreme ratios given in evidence before the Commissioners varied from one-third to one-tenth of the ultimate strength of the material. To a certain extent the fiat of the Board of Trade has extinguished all discussion on the matter among those who are engaged in designing railway structures of any description whatever. It signifies nothing what may be the private opinion of the engineer, or the results of his own actual experience. He must not exceed the prescribed allowance of four or five tons per square inch of sectional area, as the case may be; and to this inabsolute standard he must tacitly submit. There may, in some instances, be circumstances which might cause this dictum to press somewhat heavily and unfairly upon both the design and the designer, but it is impossible to avoid acknowledging that, upon the whole, the rule is sound and the limit judicious. It cannot be concealed that, with all the skill and precaution employed in testing the strength and quality of the materials which are used by engineers, it is not always possible to detect a flaw. Bars, plates, and girders of iron have sometimes, after being tested, yielded under a weight considerably smaller than that which they previously sustained without any appreciable signs of incipient weakness. When, moreover, it is kept in view that the lives and safety of the public are intimately concerned in the matter, the wisdom—in fact, the necessity—of fixing a standard that shall be well within the limits of safety becomes at once apparent. The question, however, may fairly arise—Is this limit always a safe one? May it not occasionally be minus as well as plus; and if holding good for the structure as a whole, may it not fail when applied to the separate and individual members composing that structure? This will be considered as we proceed.

In establishing a proportion between the safe or working load and the breaking weight of an iron girder, for example, it is manifest that the conditions of safety originally assumed to exist will only do so under precisely similar circumstances. Or, to put it in other words, if this ratio or limit for the statical working load be derived from a statical breaking weight, it cannot be expected to hold good when the statical load in practice is replaced by one of a dynamical and impactive character. When the conditions are altered which existed when the standard was created, it clearly is no longer applicable to the case in point. Consequently, if the strength of a bridge be sufficient to carry safely a statical or dead load, it is not necessarily sufficient to carry a rolling or live weight of the same amount with equal impunity. A bridge when it is merely supporting its own weight, and is what is termed doing nothing, is exposed to the minimum amount of statical strain. When traversed by ordinary loads it is undergoing its average dynamical strain, and when it is covered by as many locomotives as

can be got together upon it, the statical strain is the maximum any engineer or inspecting officer can possibly devise. If all these engines be run over it at their greatest possible velocity, the resulting effort upon it may be regarded as the greatest statical or dynamical strain that the structure could ever be subject to. It might be fairly asked, suppose each of these methods of loading, or rather of inducing strain, were pushed to a degree that caused the failure of the bridge, from which of them should the ratio or limit be derived? The answer will be, obviously, from the last. But is it so? has the standard been thus derived? If a girder be broken by a dead weight, or by a live load, that is a weight acting upon it with a certain degree of impact, in both instances the result is known, but there the identity terminates. In the former case the fracture is known to be due, and due solely, to one cause; in the latter it is also known to be due to a combination of two causes, weight and impact; but the exact part that each plays in the operation remains undetermined. The question is simply an "indeterminate equation," two unknown quantities being given, and only one equation from which to eliminate their value. Thus, if we consider the absolute strain necessary to fracture a bar or girder to be a constant, independently of the manner in which that strain is inflicted, the sum of the component forces producing that strain will also be a constant although their individual effect is unknown. Suppose a girder of a given length to be broken by a certain dead weight uniformly distributed over it, we also know that it will be equally broken by a certain live load or a certain weight caused to travel over it at a given velocity. But assuming a velocity, we cannot tell what the minimum weight would be; nor, assuming a weight, can the minimum velocity be predicted. Considering the breaking live load of a girder as compounded of the weight and the velocity or force of impact, it cannot be estimated *a priori*, nor, when once ascertained by actual experiment, can it be divided into its components. A constant weight travelling at different velocities over a girder will affect it nearly in proportion to the velocity, as can be plainly proved by observing the deflection; but, if the weight and velocity be varied inversely, the deflection will not be the same. If a weight of one ton be caused to traverse a bridge at a certain velocity and produce a certain deflection, it does not follow that a weight of two tons travelling at half that velocity will give rise to the same amount of deflection. The ratio of the moving weight to the insistent weight of the bridge must be introduced here, and complicates the question. Small bridges, therefore, are more exposed than large ones to this disturbing cause. Practically, the real source of danger to railway bridges from the passage over them of heavy loads travelling at a high velocity, is to be traced to a bad state of the permanent way. The condition of the road has been shown by experiments made by Mr. Hawkshaw, to very materially influence the amount of deflection produced by rapidly moving loads. From these observations it is readily perceptible that it is quite impossible to tell whether parts at least of a bridge are not exposed to a greater working strain than that prescribed by the regulations of the Board of Trade.

A very curious result, and one very much affecting the strength of girders, was elicited in the experiments undertaken by the "Iron Commissioners" in their inquiry into the mechanical effects of the impact of heavy bodies on beams. It was found that bars of cast-iron of the same length and weight struck horizontally by the same ball, offered the same resistance to impact, whatever was the form of their transverse section, provided the sectional area was constant. A bar 6 in. by 1½ in., supported upon bearings 14 ft. apart, was broken by the same magnitude of blow whether it was placed flat or on edge, and a similar force was required to fracture another bar, 3 in. square, which had therefore a different shape, but the same sectional area and weight as the former. It is not stated whether the same results obtained with bars of wrought-iron, but the inference to be drawn with respect to beams and girders of cost-iron is obvious. The strength of a girder, whether subjected to a dead or live load, is always considered to be directly as the depth, and the calculations for its proportions and dimensions are based upon that assumption. Supposing this to hold, as it does, for a statical load, the experiments alluded to lead us to infer that it does not apply to cases of dynamical loads. Instead of

the strength being directly as the depth, that quantity does not even enter into the calculation. Viewing the matter in this light, therefore, we require a different formula for calculating the strength of girders exposed to statical and dynamical loads respectively. To obtain the second of these it will be necessary to institute some experiments on a large scale, and actually break some beams and girders by a rolling load, as was done with the small cast-iron bars. There is a great and an acknowledged want of further information in connection with this whole subject. No accurate idea can be formed of the strength of any combination of parts by knowing merely that of the components; and so many new forms, sections, and arrangements of iron have been introduced in construction since the existing experiments were undertaken, that there is no reliable data to proceed upon. Had the well-known Britannia model tube been broken once or twice by a dynamical load, in addition to the fractures effected by statical loads, the results would have furnished a very desirable addendum to the valuable fund of scientific and practical information contained in Mr. Clark's book. There is little use in carrying experiments half way. Estimates of the ultimate strength of a beam or girder based upon deductions f om its deflection under certain weights—whether statical or dynamical—are neither satisfactory nor conclusive. Nothing short of the actual fracture of model tubes, beams, or girders, is to be relied upon as a datum for calculation. As an instance of the great dearth of knowledge possessed upon this point we may select open web or lattice girders. There is not a single experiment extant respecting the ultimate strength of this type of structure. We do not consider the one made by Sir W. Fairbairn several years ago worthy of the name. The specimen was designed in defiance of all the laws that are now known to apply to the principle, and was a fit example of the unscientific and crude designs that characterized the introduction of the lattice system. Under these circumstances it is not to be wondered at that the result was not in favor of the adoption of the open web type of girder, and it is not improbable that it may have in some measure contributed to retarding the development of a principle the soundness and economy of which is now universally recognized by engineers.

FIRE-PROOF STRUCTURES.

From "The Building News."

Notwithstanding that we live in a complete "age of iron," but very little use, comparatively, is made of that material in our buildings towards counteracting the effects of fire. It is true that in the majority of our new public structures timber in balk has been to a great extent replaced by cast and wrought-iron, and care is generally taken that the staircases and floors are constructed so as to be fire-proof, or nearly so. Regard is also had to these details in most of the gigantic warehouses and stores that are erected by our merchant princes. But, including all these and many more examples, the total yet falls far short of what it should amount to in a city in which fires are almost of daily occurrence. It is unquestionably more costly to build structures of fire-proof materials than of others that are not so constituted, and this is the reason why the principle is not carried into practice in buildings of secondary importance, where the first cost is the only feature considered worthy of attention. It is impossible to expect that private builders will ever introduce the fire-proof system into their trade until it be rendered obligatory by legislation. This is a step which no one can say would at the present be either fair or judicious. It must not be forgotten that buildings and houses are erected now upon much shorter leases than formerly prevailed, and there is consequently neither the inducement nor the necessity for building them in so durable a manner. We have heard it stated on very good authority that a nobleman who owns a large amount of metropolitan property will not grant a building lease on the land for more than 25 years. No one in his senses would build a fire-proof structure on a property subject to such con-

ditions, nor could it ever be attempted by the Legislature to enforce a measure of that nature, unless at the same time some radical change was introduced in the law of fixtures and dilapidations. The reversion of the tenants' property to the lord of the soil becomes too expensive an affair when durability and permanency are its distinguishing characteristics.

In all buildings the staircases, floors, and roofs are the chief elements of danger and destruction when exposed to fire. All these in ordinary dwelling-houses, and even in structures of a far more pretentious nature, are usually constructed of that inflammable material—wood. It can perhaps scarcely be advanced, so far as the safe escape of the occupants of a house in flames is regarded, that there is an absolute necessity for the roof to be fire-proof, but there is no doubt respecting the floors and staircases, or, at the very least, of the latter of these. An iron or stone staircase would, in our opinion, prove a far better mode of egress from a burning house than that which is termed, by mistake, a fire escape. Granting for the moment that this part of the question is not yet quite ripe for compulsory legislative enactments, there are undoubedly numerous instances in which the fire-proof principle in its full integrity should be rigidly enforced. By the above phrase we mean that it should not be applied to merely portions of a building, but should include the whole structure. It is not enough in these cases to leave the matter in the hands of owners of property or tenants of wharves and warehouses; for suppose one proprietor to place a large store of exceedingly inflammable and combustible goods and merchandise under a fire-proof building, and his next neighbor to keep his stock of similar commodities in wooden sheds—timber magazines—the former is perfectly at the mercy of the latter. Among the instances to which we have alluded as calling for the interference of the Legislature for the compulsory adoption of the fire-proof principle of construction, may be mentioned that of the gigantic stores, warehouses, and other erections lining the shores of our great national docks. It was but yesterday that property to the value of over £20,000 was either consumed or destroyed by a fire that broke out in the Victoria Docks. The conflagration took its rise in one of the timber warehouses used for storing bales of jute. The warehouse measured 150 ft. in length and breadth, and contained no less than 3,000 bales of jute. Fortunately, by dint of great exertion, the fire was confined to the single building, but had it spread to the contiguous ones the loss of property would have been enormous. It will possibly be asserted by some that although a building may be constructed of fire-proof materials, that will not prevent the contents from catching fire from internal causes. This is true to some extent, no doubt, for if a light were applied to a quantity of jute or other inflammable description of goods, the nature of the building that contained it would not prevent it being set on fire. But if the structure were fire-proof, it should contain in itself no element of destruction from fire, and also should prevent the possibility of it being communicated to the interior from causes of an external nature. As we proceed, it will be seen that so-called fire-proof structures are sometimes by no means faithful specimens of that principle. It may with truth be said, that excepting the desirability of saving the lives of inmates by the adoption of iron or stone floors and staircases, there is not the slightest real utility or immunity from danger obtained by making part of a building proof against fire. It is simply a "doing of things by halves," a course of action that never has and never will attain to any permanent advantage.

Speaking from a professional point of view, the three principal subdivisions of a fire-proof structure are the roof, the floor or floors, and the side walls, or carcass. Of these, considered separately, the first is the most common. In fact, any roof that is constructed of iron trussing, as a very large number are at present, in all cases where the span exceeds very limited dimensions, is, *per s*, almost fire proof, unless it be boarded over before the outer covering of slates or other material be put on. The necessity for using boards, and thus doing away, as it were, with the very principle of the roof, is, in some exceptional instances, absolutely unavoidable, as it becomes imperative to have a "cool" covering at all hazards. Even when the covering is not supplemented by boarding, unless the whole of the building be fire-proof, a conflagration, although it cannot actually consume, yet nearly invariably

destroys the roof. That cast-iron columns, beams, and girders are not fit to be erected again in the same position, was amply demonstrated by the unfortunate burning of a portion of the Crystal Palace. The carcass of this magnificent edifice is fire-proof, so far as that term applies to fire originating in any of its actual component parts, but that did not prevent the floor, which is an immense area of planking, from catching the fiery infection from the over-heated pipes and flues. A communication was rapidly established through the agency of the tall tropical plants and the various beautiful courts, to the glass of the roof and sides, which could melt, if it could not inflame ; and but for the fact that the wind was favorable to the extinction of the conflagration, there would not have been in the whole Palace "one column left on another." Had the floor of the Palace being of concrete it might not have absolutely prevented the burning that took place, but it would undoubtedly have both mitigated and retarded its course. It is very doubtful whether wrought-iron will withstand with impunity the ex reme opposite effects of fire and water, but there is no question that any cast-iron, forming portion of a building that has been through an ordeal of that description, is utterly unsafe to be again employed for any purpose of construction. It is only fit for the melting pot. At the same time we have very strong suspicions that many of the columns and joists forming portions of the *debris* of the Crystal Palace fire, which were sold by auction or disposed of by private contract, have been placed in positions where they are still doing duty. To proceed still further, there are not wanting instances in which buildings erected in every sense upon a fire-proof principle have been as totally destroyed as if they had been constructed of the most inflammable materials. The latest example is one which happened about a week ago. Some very extensive flour-mills, scarcely four miles from the town of Cork, were entirely demolished by this cause for the second time. After the first occurrence, it was determined by the Company to reconstruct the mills on the fire-proof system, which had not been adopted in the first instance, in order to obviate the danger of a second conflagration. No pains nor expense were spared to insure this object, but all the precautions failed to avert the result, which has reduced the whole premises to a mass of ruins, including some very powerful and valuable machinery. In the face of these facts, the construction of a really fire-proof building appears to be a question yet to be solved, and the prospect does not seem very encouraging. While there are unquestionably some fire-proof systems of a *bona fide* reliable nature, there are a large number so called which are worthless, as well by the materials used as the manner in which they are disposed and put together. There is a great deal yet to be done in this particular branch of constructive art. At present we have only made a commencement, and not a very good one either. There is plenty of room for improvement, and we do not doubt that it will soon become manifest, especially if the Legislature turns its attention to so important a subject, which is so vitally connected with the safety and welfare of all great cities.

The Paterson "Press" says : "The reconstruction of the Rogers Locomotive and Machine Works will not be carried any further this year. The immense new mill lately erected is gradually getting into operation, and in a few months will probably be entirely in use. It is driven by one of the finest overshot wheels in the city—an 80-horse power affair. The next rebuilding, it is thought, will be at the corner of Market and Spruce streets, but that will not be started before next spring."

Quality of Ice.—The French steamship company (Les Messageries Imperiales) having to ship a quantity of ice to Suez for the use of its steamers in the Indian ocean, and desiring to find the best quality for their purpose, subjected 220 pounds of several kinds to the same conditions of temperature, with the following results :—Natural ice from Switzerland lasted 107 hours ; natural ice from Norway, 115 hours ; artificial ice, made by the Carre machine, 130 hours ; natural ice from Boston, Mass., 138 hours ; artificial ice, made by the Tellier machine, 144 hours. Artificial ice, then, appears to be as solid as natural ice.

RAIL MENDING.

From "Engineering."

The days of magnificence and prodigality in the management of the funds of even our best paying railways have long since departed. Gradually melting dividends sooner or later failed not to rouse even the most confiding and befogged class of shareholders, and the wail of their *coronach* over departed incomes summoned to their rescue a whole host of railway doctors, and possibly a still more imposing host of quacks. The first incidental advantage of this movement was to supply a healthy amount of light and ventilation to the close bureaux where railway affairs were doctored; and, beyond that, the knowledge was soon attained that those who promised most performed the least, and that, not in heroic remedies, but in the exercise of economy in innumerable minutiæ, was the improvement of the financial state of railways to be sought.

The attainment of this preliminary step at once started railway economists on a fruitful voyage of discovery. A few steps forward disclosed to them the existence of a wide field for the ingenuity of inventors, in the development of improvements calculated to reduce the enormous current expenses of that all-essential portion of every railway—the iron road itself. It appears hardly credible at first that one of our railway companies alone should have expended upwards of £2,000,000 sterling in mending its roads, but such is the indisputable fact. Under that head the annual expenditure of the London and North-Western Company is over £100,000; of the North-Eastern some £60,000 to £70,000; and of the Great Northern nearly £50,000 sterling. Upon heavily worked portions of a railway, 20s. per day is not too high an estimate of the tax upon the receipts to maintain each mile of line in proper condition for traffic; and on average lines this tax would seldom be reduced more than 50 per cent.

The cause of this enormous charge is not far to seek; it is at once traceable to the inherent defects of the iron rails themselves. One of our best authorities, Mr. Menelaus, the manager of the largest iron works in this kingdom, did not hesitate to assert, in the presence of the largest muster of ironmasters ever assembled at the Institution of Civil Engineers, that it was commercially impossible to manufacture an iron rail which would satisfactorily sustain the present traffic of many of our lines for any reasonable length of time. The truth of this proposition may be made apparent, even to railway directors, without any technical knowledge, if we consider for a moment the requirements in a rail on the one hand, and the process of its manufacture on the other.

A perfect iron rail will be one which is sufficiently strong in every direction, and which, consequently, will remain serviceable until the head shall be fairly worn away by abrasion. Now, as far as the resistance to crushing under the rolling wheels is considered, we know that no trouble is to be apprehended in the direction of the length of the rail; for each particle of metal is there kept up to its work by its neighbors; and as it cannot escape, the particle cannot be crushed—for the same reason that water cannot be "crushed" in an hydraulic press. If crushing occur in a rail, then, the particles must move laterally; or, in other words, the head of the rail must widen out. To resist this tendency great strength is required in the metal in a direction at right angles to the length of the rail; and to attain this strength in wrought iron, as in wood, the fibres should run in the same direction. To obviate the frequent splitting of the longitudinal sleepers in the Great Western road, short pieces of wood are inserted crossways between the rail and sleeper; how to remedy the same defect in wrought-iron rails is not so apparent.

We require strength, and consequently, at least some pretence of fibre, at right angles to the length of a rail, but what do we get in practice? By the ordinary process of manufacture, the rail pile has a top and botton slab of No. 2 iron roughed down from puddle bars, so that every particle of metal in the wearing portion of the rail has undergone the following processes: The original fibreless bloom has been shingled or hammered, and passed through the puddling train, by which every particle of iron has been extended to some ten times its original length in one direction. The resulting puddle bars

have been cut, piled again, and again extended, in going through the rolls, to some six times their length. The slab so formed has been extended once more some ten times in rolling the finished rail, so that every particle of iron in the head of the rail has been elongated in one direction some six hundred times, and reduced to a corresponding extent in the other. The finished rail then consists of a bundle of fibres, and when we consider all the exigencies of practice, and the difficulties in completely excluding foreign bodies from the numerous layers of bars in the several piles, we cannot be surprised that an iron rail is frequently stigmatized as a bundle of wire cemented together with cinder. Changes may be rung in the mode of manufacture, hammered slabs may be substituted for puddle bars, and the fibre may, to a certain extent, be modified by cross piling, but the broad fact remains, as stated by Mr. Menelaus, that it is commercially impossible to make a perfect iron rail.

Steel rails, of course, meet all the requirements of practice, but the great mass of railways in the world are still iron roads. This being so, the question of paramount interest to all railway authorities is how to make the best of the existing condition of things. A satisfactory answer to this question has been obtained on the other side of the Atlantic, and the solution of the apparently complex problem is so simple and complete that the only wonder is that it was not stumbled upon before.

Mr. Baines, a Canadian, tells us to mend our rails, not to sell them for old iron because they are crushed or split for a few feet in one or two places, whilst the remainder of the rail is as serviceable as ever. "Put on a patch," says Mr. Baines.

Now, were not the imperial days of railway management, as we have already maintained, for ever vanished, the suggestion of a patched rail would no doubt have been treated with withering contempt, as a thing to be mentioned only in the same breath with chiffonniers, footless hose, and amorphous hats. But at present, notwithstanding Lord Chesterfield's dictum, that a man of fashion never has recourse to proverbs and vulgar aphorisms, in the maintenance of the way and works of railways it is the fashion to act rigidly upon the maxim that "a stitch in time saves nine." The system of repairing rails invented by Mr. Baines, enables us to do this in the instance of the most important item in railway maintenance—the rails themselves.

We cannot reasonably expect a bundle of particles of metal, elongated as we have shown to some six hundred times their original length, to be in many instances welded uniformly well throughout the r entire length, and in practice we do find a defective weld in almost every rail. Under traffic this weak weld is burst open by the hammering of the passing wheels, and the rail becomes more or less split and indented. The rail may be, and generally is, practically intact elsewhere, but this one weak spot cannot be eradicated, so the rail is discarded, to afford another illustration of the paradoxical proverb applied by the Greeks to law arbitration, *et hoc genus omne*—that the half is better than the whole.

Now the mode of procedure in such an instance, in Canada and the United States, where Mr. Baines's system has been in full operation for some years, is so simple, that the sacrifice of the rail becomes almost culpable. The apparatus invented by Mr. Baines has already been fully illustrated and described in this journal, vol. vii., p. 236, but the *rationale* of the process may be exhibited in a few lines: A piece of bar iron of the requisite length is placed upon the damaged portion of the rail, and, together with that portion, is raised to a welding heat in a furnace specially designed for the purpose. At the proper moment the rail with its patch is withdrawn, and the heated portion passed through rolls corresponding to the finished section of the rail, by which means the rail is restored to its original form at the damaged point, and its inherent weakness there is completely remedied by the addition of the new piece of iron, and by the rewelding of the originally imperfect weld which induced the damage. It is no matter for surprise, therefore, that a mended rail is rarely found to yield again at the same point. The patch becomes an integral part of the rail, and no traces of the weld are visible upon the closest inspection of a cross section, fractured either by steady pressure or by a blow.

At the present time, six thousand miles of railway are enjoying the benefits of this invention. The Great Western of Canada were the first to try the system, and after

three years' test they have just erected a mill at their own cost to repair the rails upon 300 miles of line, for which they pay royalty up to £10 per mile. The Chicago North-Western have 3 mills finished or in progress, to serve their 1,800 miles of line, and many other American lines are availing themselves of the proved advantages of Mr. Baines's invention.

An experimental mill is now in operation in a small back yard, not 100 miles from Charing-cross; although anything but imposing in appearance, it is stated to be equal to the repairing of the rails on 250 miles of line, when it would effect an estimated saving to the Company using it of £5,000 yearly on a capital expenditure of about £3,000. Test rails are now being repaired for the London, Chatham, and Dover, and other companies. No doubt there is ample scope for the development of the system in this country, since, notwithstanding our exceptional national advantages, the cost of re-rolling rails must be at least ten times that for which they can be repaired. In India, where thousands of tons of rails are lying in purposeless stacks, the adoption of Mr. Baines's system, or something analogous to it, has become a necessity.

THE APPLICATION OF THE HOT BLAST TO BLOWPIPE PURPOSES, AND THE PROPOSED SUBSTITUTION OF HEATED AIR FOR OXYGEN IN THE PRODUCTION OF CERTAIN THERMAL AND ILLUMINATING EFFECTS.

By W. SKEY, Analyst to the Geological Survey of New Zealand.

From "The Chemical News."

The useful and well-known effects of the hot blast, in the process of iron smelting, has induced me to try and extend it profitably to other purposes, beyond that which prompted its application in the present instance. My experiments, as yet, have been confined to testing the effects of substituting a hot blast for a cold one, as hitherto used, for the production of the well-known blowpipe flame; a flame so produced will be expected to have its thermal and illuminating effects augmented, but scarcely, perhaps, to that degree which experiment has demonstrated. I had better state, at the outset, those particulars which it is necessary to know, before relating the results. The temperature of the blast was, approximately, 500 deg. Fahr.; the diameter of the jet, regulating its issue, was 1-30th of an inch; the combustible for receiving the blast was stearine. This flame manifested a very marked superiority over the common blowpipe flame—substances difficult to fuse in the latter, magnetite, potash, felspar, mica, readily yielded under these circumstances; while thick glass tubes, half an inch in diameter, and hard German glass tubes, were tractable to an eminent degree. Carrying my test experiments still further, I found several substances, for the fusion of which the oxyhydrogen flame, or some equivalent of it in heating power, is said to be indispensable, also yielded before the blowpipe flame thus urged; for instance, platinum, pipe-clay, fire-clay, agate, opal, flint. Several samples of each were tried, and always with the same results; it could not well be, therefore, that the fusibility of any of these substances was due to the accidental presence of foreign matter, in more than usual quantity. The platinum was the common platinum foil, also a sample prepared especially for the purpose; the only impurity found in it was iron, as traces, communicated to it in the act of forging; possibly minute quantities of some of the other metals of the platinum series might be present, but they would rather tend to increase its infusibility than otherwise. Alumina only appeared to vitrify; while, after numerous trials with crystallized quartz, I could not succeed in fusing it to a globule; thin splinters, however, curled round upon themselves, like scolezite, and ultimately assumed a glazee appearance, clearly showing that the melting-point was all but reached. It appears, from this, that a very small amount of some foreign substances exercises a marked effect upon the fusibility of silica, agate, opal, etc., being only a little less pure than rock crystal,

though so readily fusible in this flame. Regarding the illuminating power of the flame so produced, when allowed to impinge upon a solid substance, such as lime or magnesia, it was not only more intense (as would be expected), but the volume of incandescent matter was largely increased. Before I proceed to urge the further use of hot air for combustion, where high temperatures are necessary, I wish to call attention to the fact, that the temperature of the flame, which I have hitherto worked with, can be largely and economically increased by increasing that of the blast; this can easily be done to a threefold extent. By substituting heated hydrogen (or burnt coal-gas), I have also realized all the effects just instanced, with greater rapidity and decision; but the great diffusiveness of this gas, especially when heated, has prevented me, as yet, carrying the experiments further.

While on the subject of heating both combustibles (at least, both the substances which take part in these combustions), I cannot refrain from remarking how easily the temperature of the oxyhydrogen flame, even, could be increased in this manner—the gases would, of course, have to be heated prior to contact. Upon their more vigorous diffusiveness, when rarefied, I should rely for that solidity of flame so necessary where the communication of very high temperature is desired. The jets regulating the issue of the gases would have to be very fine. Proceeding now to the next part of this subject: the result of these experiments, instanced, urge me to recommend, for trial, the substitution of heated air for oxygen, in most of those cases where this gas is now employed in conjunction with hydrogen or other combustible matter, as a generator of heat of light; for instance —1. In the metallurgy of platinum, that part of it where the metal has to be fused; also in soldering platinum stills for sulphuric acid works. 2. The fusion of alumina in the manufacture of certain gems. 3. In the production of the Drummond and Bude lights. The fusion of platinum and alumina is now effected by the oxyhydrogen flame. Relative to the competency of heated air to perform the part of cold oxygen in the production of such intense lights as these (the Drummond and the Bude), I think this can be demonstrated, almost to a certainty, in the following way:

Thus, the flame employed in these investigations has certainly a minimum temperature of 4595 deg. Fahr., since this is the fusing point of platinum, the substance most easily fused of all those I have tried that are infusible in the common flame; doubtless the temperature is considerably higher, but I will take these figures. On the other hand, the actual temperature of the lime, when the Drummond light is in operation, is (on the authority of Tyndall) only 2000 deg. C. = 3632 deg. Fahr.; hence this flame has an excess of temperature over that of the incandescent lime equal to 964 deg. Fahr., a pretty good margin for loss, surely sufficient if properly economized; but as I have already shown, this excess of temperature can be largely increased. In view of the greater controllability of the proposed substitute, the absence of all danger in its use, its not requiring chemical preparation, and its cheapness compared with oxygen; upon these several points, respectively, the question should be properly tested. Besides the substitution of oxygen urged above, the possible fusion of the purer clays and certain silicas, etc., in a ready and economical manner, may induce the further utilization of these substances, while in experimental chemistry, the facility with which such high temperatures can be attained and kept up may lead, among other things, to some cheaper way of extracting certain metals from their oxides—for instance, from alumina or clay.

On reviewing these results, it does seem not a little singular that a difference of not more than 500 deg. Fahr. as the temperature of the blast should make the difference between the fusibility and infusibility, of such substances as platina, agate, fireclay, etc., in the blowpipe flame. It will be recollected, however, that the blast has, in this case, not only taken up the heat required to raise a single volume of it to this temperature, but another portion of heat has to be taken up in a latent form, as the air expanded—consumed as it were in lifting against the atmospheric pressure; this may be represented sufficiently well for us, by assuming the temperature of the blast, kept to its normal volume, at 700 deg. Fahr. This is as yet, however, but a very slight addition to

produce results, which so nearly approximate to those obtainable by the oxyhydrogen flame, seeing the latter has an estimated temperature of 14,000 to 15,500 deg. Fahrenheit, while that of the present method does not much exceed 5,000 deg. Fahrenheit. The gap, as far as effects are concerned, is narrowed so much, and in a manner so unexpected, by the results here given, that one is naturally prompted to inquire whether the assigned temperature of the oxyhydrogen flame has been obtained by direct experiment, or by calculations, based upon the ascertained temperature of other flames. The temperature as calculated, indirectly, in this last way, certainly furnishes us with figures remarkably close to those just quoted. In reference to this important point, I beg to call attention to a notice which appeared in the "Chemical News," relative to the imperfect combustion of certain gases at high temperatures. There we learn that at moderately high temperatures (much below 10,000 deg. Fahr.) oxygen and hydrogen only very partially combine—from memory, I believe, not more than to the extent of half their weight—the remainder of the gases of course combine, as the centre of heat is left behind. Thus, although the quantity of heat evolved by their combustion is the same, being divided over a larger volume, its intensity is proportionately diminished. This being so, it would seem to follow that the temperature of the oxyhydrogen flame must be very considerably lower than that hitherto ascribed to it; and, therefore, the possibility of substituting it in this, or in some other manner equally economical, for the several purposes here specified, appears so much the greater.

TRACTIVE POWER OF LOCOMOTIVES.

From "The Railroad Gazette."

The power of any locomotive is limited by the *friction* or resistance to slipping or sliding between the tread of the driving-wheel and the rail. The word "adhesion" is sometimes used in this connection, but it can be applied with correctness only to a resistance like that which is offered to the shearing of a body, as a bar of iron, in which the particles of the metal are forced to move or slide upon themselves while the shearing is taking place. Hence the ability of an engine to move a load will depend upon *the weight resting upon its driving-wheels and the condition of the surface of the rail*, because the most careful special experiments and extended observation in practice show that, in common with metals so nearly similar in character as rails and tires, whether of iron or steel, the friction is almost exactly proportional to the perpendicular pressure between the surfaces, or, in the case of the locomotive, to the pressure upon the rail. It is by this friction that the wheel is prevented from revolving freely when pressure is brought upon the piston, and this friction is always greatest, and the engine can draw the heaviest loads, when the rail is either perfectly dry or perfectly wet, so that the surface of the tire may come into close contact with the surface of the rail without the intervention of any slippery film of moisture.

The general law, deduced from the most exact experiments, is that the force required to move one body when sliding upon another corresponds very nearly to the perpendicular pressure between them multiplied by the *co-efficient of friction*. This co-efficient is simply the relation or proportion which the pressure required to move a body upon any surface bears to the weight of the body itself, and for general purposes may be stated to be from 1.20 to 1.10 between metals when properly oiled. If the surfaces are not properly smoothed, or if the pressure between them is so great as to produce grinding or abrasion, then this law will not hold good, but the co-efficient will increase rapidly to a point determined by the special condition of the case. It is also evident that this co-efficient or proportion will diminish when the surface sustaining the weight of the rail, in the case of the locomotive, becomes more slippery than usual, as when snow or ice accumulates on the track, or sometimes during a slight rain, and hence, as is well known, the tractive force of any engine may be very greatly reduced at such a time.

Since, then, the power of a locomotive

depends so entirely, other things being equal, upon the weight carried upon its driving-wheels, it might seem necessary merely to increase the total weight of the engine by loading it with pig-iron in order to increase its tractive powers ; but further consideration will show that this is not true. To illustrate the actual state of the case, suppose a locomotive to be firmly attached to a solid rock which cannot be moved. If steam be then admitted to the cylinders, a pressure will be brought upon the driving-wheels tending to make them revolve, and, in this supposed case, they can only slip upon the rail. This slipping will always take place when the pressure upon the piston, due to the steam within the cylinder, is greater than the product of the weight of the engine multiplied by the co-efficient of friction, since, as has already been shown, there is no other means than this of holding the wheels to the rail. Slipping will not occur in this case if the pressure upon the piston is less than the product of these two factors. If the weight of the engine be not great enough to prevent slipping for any given size of cylinder or pressure of steam, then an increase of weight may usefully be made, so that this product may be increased by which, as has been shown, the tractive power of the engine is measured or limited.

It will be seen, then, that with any given size of cylinder and standard pressure of steam a certain weight must be given to the locomotive, so that, under ordinary circumstances of weather, etc., no slipping of the wheels may occur, and also that no useful result can be obtained by increasing this weight beyond this certain amount ; for the pressure upon the pistons cannot be increased beyond this assumed limit, and hence no additional load can be drawn, even though no slipping should take place.

The objection urged against the use of six-coupled engines, that they have a long rigid wheel-base, is an important one, and it is receiving serious attention in England, where these engines are vastly more common than in this country. Few builders, however, would put 3 pairs of driving wheels under any engine without making the boiler and other parts longer or heavier, so as to furnish a weight to be borne upon each pair of wheels equal, or nearly so, to that borne by each pair of wheels of an ordinary four-coupled engine, so that the larger engine may be efficient just in proportion to its size.

The grand objection to any increase of the weight of our engines, as now constructed, is that it is too destructive to the track to load each pair of wheels even as heavily as is ordinary now. The blows dealt by passing wheels upon the rail-joints, and the bending or breaking strain brought at any instant upon the joint in the rail where a wheel presses, depend upon the weight which the wheel carries, as well as the speed at which it moves ; and hence to diminish our track repairs, that which is nearly or quite the most greedy of all maintenance accounts, the load borne per wheel in our locomotives must be lessened at least one-half, so that it may more nearly agree with the load borne per wheel in the cars. How this can be done without increasing the rigid wheel-base while the present boiler and cylinder capacity are retained, is one of the most trying problems of the present day among locomotive builders, and certainly the most promising commencement of its solution is the introduction of the Fairlie engine, notwithstanding the numerous complications with which it is still beset.

A PROJECT is on foot in St. Louis to build an immense structure, to embrace under one roof a grand union railroad depot, custom-house, merchants' exchange, hotel, railroad office, and other places of business buildings, to occupy three entire blocks, from Fifth street to Eighth, and from Washington avenue to Green street. This includes the site of the burned Lindell Hotel. From the bridge now building, trains would pass through the tunnel under Washington avenue to the passenger depot, which would be twenty-two feet below the surface of the ground ; thence westward to a great union freight depot, to be erected on the ground formerly covered by Chouteau pond, and through which the Missouri Pacific Railroad runs. The building is expected to cost $3,000,000.

THE Rensselaer and Saratoga Railroad Company are laying steel rails between Saratoga and Ballston Spa.

THE SEWAGE OF THE AIR.

From "The Engineer."

It is admitted universally that the great subject of the disposal of our town sewage is the all-important engineering and chemical topic of the day, but the parallel case which is embodied in the question, How are we to neutralize in the best possible manner for all parties concerned the evils resulting from the discharge into the atmosphere of the waste gases of our factories?—though scarcely inferior to the former in importance, has not attracted so much attention. The reason for this indifference is, perhaps, to be found in the fact that, considered as a nuisance to inhabitants or individuals, the annoyance caused by the fumes from the various manufactories is easily remediable under the Sanitary Act, while its equally important action upon vegetation and the crops of the farmers is not brought so prominently before the public, partly because of the apathy of the farmers themselves, and partly because of the difficulty of obtaining any redress. In the former case the remedies are clear, and the law is easy to set in motion, but in the latter the law is not so clear, and there are fewer parties interested who have the courage to enter upon the lengthy proceedings which frequently end only in greater loss to their promoters. In the one case the nuisance being obvious, easily traceable, and affecting large masses of the population, the law simply imposes penalties until it is stopped; but when the crops and fields only are injured the question resolves itself into a matter of damages, perhaps to be followed by an injunction, if the injury be severe and lasting, thus necessitating a long and costly suit at law. The question is not whether any damage has been done, but how much—for obviously it would be an impolitic act to cripple by legal enactments, the producing power of a manufactory which does a vast amount of good at the expense of a smaller amount of injury to the neighboring farms. But the manufacturer, who may be enjoying a handsome return from his works, ought to recoup the farmer the amount of loss he may have sustained through the ruin of his crops by the destructive vapors from the said manufacturer's premises. It is immaterial to the farmer whether he gets his money from the produce of his farm or as damages from his neighbor; and a man who is enjoying a good income from his business surely cannot object to part with some of it to enable him to keep the rest in comfort. So far so good; but now the difficulty arises, how is the amount of damage, and consequently the amount of compensation, to be ascertained?

If there be only one factory which causes the evil the matter is simple. The farmer has only to show that the smoke from this factory falls on his land, and that his crops are injured to a given extent. When, however, there is an aggregation of such works, each, perhaps, giving off variable quantities of acid vapor, and situated at varying distances from the complainant's land, the latter's difficulties commence. If he fix upon an individual manufacturer and attempt to saddle him with the whole of the damage, he will probably be shown that he is not acting in perfect fairness to the defendant, who will point to his neighbors, and will show that he alone did not produce all the injury, and that he should not, therefore, be called upon to make good all that the farmer demands. In the face of all these difficulties, then, we cannot be surprised that so few efforts are made to wrest from the owners of factories compensation for the injuries they cause.

An attempt was made in 1863 to remedy this crying evil by the passing of the Alkali Act. It was admitted that the hydrochloric acid vapor which is disengaged in large quantities during the process of the manufacture of alkali from common salt, was the greatest cause of the destruction of vegetation, and this Act was therefore directed towards the evil. It then became law that every alkali manufacturer should condense at least 95 per cent. of the hydrochloric acid vapor, and inspectors were appointed who had full powers to enable them to ascertain whether the stipulations of the Act were properly complied with. If the inspector detected any infraction it was his duty to give prompt notice to the manufacturer, and if this did not prove sufficient he was empowered to institute proceedings, with the consent of the Board of Trade, in the County Court

of the district to which the offending factory belonged. This Act, which after all was more an experiment than a comprehensive legal measure, has been completely successful in its operation. As a matter of fact, manufacturers frequently condense more than 95 per cent. of the acid vapor, to their own enrichment, and the more effectually this condensation is performed the more perfectly and economically is the factory known to work. The public, however, cannot expect to rest satisfied with an enactment which can only apply to one out of the legion of processes which inflict equal injury, and it is here that we think it is imperative that some further steps should be taken. Let us see what provision is made on the Continent in similar cases.

In France legislation on these matters is founded on what may be called the preventive system. The law fixes a general principle, and leaves the execution of the means of carrying it out to the local authorities. Each prefect, aided by his *conseil d'hygiène*, gives permission to each of the factories of his department to work, and he binds them to observe certain regulations which he lays down to guide them in carrying on their processes without injury to the public good. The authorization prescribes the mode in which the nuisance of waste gases is to be prevented, and will not allow any deviation. To insure that these regulations shall be properly obeyed, a power of inspection is conferred on the local authorities, which, in the majority of cases, is exercised by the police. What is the consequence? A few of the larger and better-conducted manufactories observe the rules, but the greater number of the small works ignore them altogether, and in many instances go to work without even the necessary authorization. Complaints, however, are rare, apparently because of the apathy frequently present among people who endure a nuisance in common, and also because of the reluctance of each one to be first to push for the redress of an abuse. Moreover, the rule which compels the use of a given method of prevention, dependent, as it is, upon the scientific knowledge or experience of the *conseil d'hygiène*, frequently ends in an inefficient means being adopted, and probably checks invention. The system of inspection has not been found to work well, and some of the departments have, we believe, appointed efficient inspectors, whose sole duty it is to attend to the various factories in their districts; but still there are no central Government inspectors. Popular feeling, too, has lately set against the strict regulations of the departmental officials, and the decree of 31st December, 1866, prepared under the advice of the *Comité Consultatif des Arts et Manufactures*, has removed much that was objectionable. One of the consequences of this improvement that has been noted is, that strenuous efforts have been made to discover the best method for the absorption of nitrous vapors, and the destruction of the sulphuretted hydrogen.

In Belgium the law has moved upon the same principle as in France, but the general tendency is to follow the English model. Here the inspectors have full powers. They are allowed to enter works at all hours, to assure themselves that the rules of the establishment are being complied with, and the proprietor is bound to produce, if required, the plans of his works, and the official documents which regulate his course of manufacture. Still, there is a feeling that all restrictive enactments should be swept away, and that Government interference should be confined merely to the prevention of public nuisance. Thus while manufacturers would be freed from rules confining them to certain processes of manufacture, the local authorities would be further strengthened by Government inspectors in their efforts to preserve the public health. It may not be out of place to give an instance here of the way in which the Belgian law fails to fulfil its purpose, and it is evident that similar cases might arise under the French law. Not long ago the Brussels Committee of Health declared, in relation to complaints respecting a certain factory in that city, that although the complaints were well founded the manufacturer had been careful to keep within his regulations, and so no help could be given. The Committee went still further, and even declared its inability to make any additional regulation to meet the case. In Prussia also the principle is the same as in France, but inspection is more active. It is confided, for all kinds of manufactories, to the communal authorities, who in their turn exercise it through their architect or engineer, generally a man specially ac-

quainted with the working of industrial establishments. This power of inspection is further strengthend by the addition of Government inspectors, who proceed to places where cases of importance may require settlement, and who also afford the benefit of higher knowledge and experience to their local brethren. This system has resulted in the prevention of any great abuse, but it would also seem to have suppressed that spirit of invention and research which is so remarkable in England.

These, then, are the various practices of other countries, and it is quite clear that we should not be gainers by their adoption in our own. The extension of the existing Alkali Act to comprehend other manufactures, and no more, would not suffice, because it would not do to include in the operation of an Act a process for the attendant nuisance of which there did not exist an adequate remedy. A good suggestion, however, has been thrown out by Mr. A. E. Fletcher, who is, we believe, an inspector under the Act for a portion of Lancashire. That gentleman suggests that in places where complaints are made by farmers against manufacturers, of damage done to their crops by corrosive smoke, the district should, upon the requisition of a certain number of inhabitants, be called a manufacturing district. To such a district an inspector should be appointed who should have power at any time to ascertain the nature and amount of the gases escaping from the various works. At the end of each month, or longer period, he should publish a list of all the works in his district, with a number indicating the average amount of acid vapor he had found on his separate visits. Here his duties would end. He should be neither prosecutor nor judge. He should simply publish the facts he ascertains, those facts which the farmer could never ascertain. It would thus become necessary to the manufacturer to adopt every means in his power to limit to the utmost the emission of noxious vapors, and he would probably find the introduction of even costly methods economical, provided it raised his place in the list, and so diminished for him the farmer's claim. This proposal is certainly practical, and coming, as it does, from one who has seen much of the actual working of the evil, is all the more valuable; but the whole question requires careful consideration. There are so many conflicting interests and details to be observed and provided for, that it is necessary to advance very cautiously in working out a perfect system. Nevertheless, the suggestion deserves serious consideration. We shall probably return to the subject of atmospheric pollution before long.

ELECTROLYTIC INSULATION.

From "The Electric Telegraph and Railway Review."

We have to direct the attention of our telegraphic readers to a novelty in electrical science, and to a question which may, or may not, become of great practical importance in electro-telegraphy,—more especially in connection with under-ground lines. This novelty—for it is a new application of old facts—is what has been termed Electrolytic Insulation; and the question is whether this mode of insulating a current, or, rather, of insulating from each other two conductors forming the "sending" and "return" paths of a current, can be utilized for telegraphic circuits. We will first describe what electrolytic insulation is; and we will then state what we know of the results which have hitherto been obtained in its experimental application.

Supposing that we are called upon to insulate from each other two wires respectively attached to the terminal elements of a battery—say of four Daniell cells; the plan which first suggests itself is simply to place these wires apart *in air*, or in other words to utilize this common dielectric for the purpose of insulation. If, however, the wire be several hundred yards in length, we have to use another dielectric—stoneware or porcelain, glass or ebonite, etc.—at the points of support. Or, we may completely encase one of the wires in a dielectric of another class, such as gutta-percha or india-rubber; using

the uncovered wire, instead of the earth' for the return current.

All these are examples of *dielectric* insulation. But the wires may be insulated from each other, under any given electromotive force, "by means of good conductors of electricity (metals and electrolytes) so arranged as to generate an electromotive force which opposes the escape of the current when the latter is transmitted in a particular direction."* The insulator is then electrolytic. If, for instance, we respectively connect the wires above mentioned to the poles of another battery of four cells of Daniell, so that the electromotive forces of the two batteries may be opposed to each other, no current will pass; although a complete conductive circuit exists. Now this second battery—which is not required to transmit a current, but merely to exert statically a certain opposing tension or electromotive force—may be constructed in the form of an elongated cylinder, of any required length, composed of a tube, or series of concentric tubes, having as a central element the wire to be insulated. The tube, or tubes, and central element, being metallic, and being separated from contact with each other by means of a fibrous material containing an electrolyte, or moisture, constitute in fact a voltaic battery (if the opposing metallic surfaces be dissimilar), or a secondary battery (if the opposing surfaces be similar). The poles of this battery will be constituted respectively by its outer surface and the inner conductor; and the number of cells connected in series, and consequently the electromotive force of the arrangement, will be as the number of concentric tubes. It will be seen, therefore, that if the poles of a Daniell battery of equal electromotive force be respectively connected, through a galvanometer or other indicative instrument, with the poles of this elongated battery, at one of its extremities, no current will pass through the conductive circuit thus constituted *until the poles at the other extremity be brought into metallic contact.* When this occurs, there will be a complete *metallic* circuit, free from any opposing electromotive force for the current from the Daniell battery; and thus current, starting from one pole of the latter, will traverse the inner conductor of the cable-battery and the wire uniting its poles at the distant extremity, returning by the external tube, or *vice versâ.* Signals may thus be produced, at one extremity of the cable-battery, by uniting its poles at the other extremity.

Professor Miller, F.R.S., of King's College, thus describes an experimental or model cable on this principle, and some of the results obtained with it, which have not hitherto been published:—

"The cable was made in a series of lengths of a yard each. I was informed that each of these lengths consisted of a conducting core of galvanized iron wire 1 yd. 2 in. in length, coated with a fibrous material—this coated wire was enclosed in a soldered leaden tube 1 yard in length. The tube was then covered with thin zinc foil, and this in its turn was coated with fibrous material. The whole was then enclosed in a second leaden tube 1 yard long. Each layer of the fibrous material had been previously steeped in a strong solution of sulphate of magnesia, and allowed to become partially dry by exposure to the air.

"The composite tubes prepared as above described were laid side by side on an uninsulated wooden table covered with sheet lead (earth). The projecting ends of the galvanized iron core were connected alternately with the wire adjoining, by means of binding-screws and short pieces of copper wire, so as to make one continuous conducting cable, of 97 yds. in length; the three other lengths needed to make up the 100 having been damaged.

"One extremity of this conducting wire was attached to a galvanometer and through this, by means of a commutating key, was permanently connected with the negative pole of a two-celled Daniell's battery, the positive pole of which was connected with the 'earth,' or with the outer surface of the cable through the leaden table.

"The other end of the cable was connected with a series of three resistance coils, consisting of 1,000 yds. of fine silk-covered copper wire, 32 gauge; and the other end of these resistance coils was insulated, but could be connected to earth at pleasure by means of a key.

"Every time that this connection of the earth with the galvanometer was made, the needle of the galvanometer was strong-

* Specification of Letters Patent to D. G. Fitz-Gerald, dated 18th February, 1860, No. 501.

ly deflected, and signals were transmitted through the resistance coils and cable.

"When thus arranged, the entire cable itself formed a battery of two cells, acting so as to produce a current in the *opposite direction* to that generated by the signalling battery, the electromotive force of which latter somewhat exceeded that of the current which the cable tended to produce, but which it did not actually furnish.

"That this really was the case was shown by reversing the direction of the current from the signalling battery, so as to cause it to *coincide* in direction with that from the cable. The galvanometer was immediately deflected with energy, and the needle thrown against the stop at 90°. The insulation effected by the cable was thus shown to be due to the electrolyte and not to any interposed dielectric."

It is not often that a fundamentally new system of constructing electric telegraph lines, "ingenious, and founded upon a principle the correctness of which cannot be doubted in the main"—as Prof. Miller states the present system to be—is brought to our notice. Whether or not this device of electrolytic insulation be susceptible of being adapted to the practical requirements of telegraphy, it merits attention, and should be studied by advanced telegraphists. Our opinion is, that if certain mechanical difficulties in the construction of an electrolytically insulated cable can be satisfactorily overcome, this system might certainly become available for underground lines. The competent opinions which have been given as to the durability of such a cable are very favorable; metallic corrosion being obviated by the application of the principle upon which Sir H. Davy protected the sheathing of ships, whilst the decay of the fibrous material would not appear to impair its electrolytic property, nor to lead necessarily to any metallic contact between the elements of the cable.

We have recently witnessed an experiment—which may readily be repeated upon a small scale—with a modification of the apparatus above described, in which the "thin zinc foil" was dispensed with. The cable, at first possessed of no insulating power, becomes converted into a secondary battery by the passage of a strong current through it laterally from the inner conductor to the outer tube, or *vice versâ*. We may suggest the following miniature reproduction of this experiment to those of our readers who have time and taste for investigation. A galvanized iron wire 20 in. in length may be covered uniformly with hemp or cotton fibre, which is to be moistened with a solution of sulphate of magnesia (Epsom salts). This coated wire is then to be inserted into a leaden tube, 18 in. in length, the internal diameter of which should be just sufficient to allow of the insertion. If the negative pole of a Daniell's battery of 4 or 6 cells in series be now connected through a galvanometer (or "quantity" indicator) with one end of the inner wire, and the positive pole be connected with any portion of the tube, a strong current will traverse the arrangement. It will be noticed, however, that this current rapidly becomes weaker, and, when its intensity has fallen to a sufficient extent, it will be found that the arrangement, which has now become "polarized" or converted into a secondary couple, will insulate the current from one—or perhaps nearly insulate that from two—cells of the primary battery. Signals through the miniature cable may now be obtained by momentarily bringing the free end of the inner wire into contact with the tube. If this tube be in turn covered with fibrous material, as in the case of the inner wire, and inserted into a larger tube of lead, the cable, when subjected afresh to the process of polarization, will have acquired a double insulating power. By connecting up a battery through a galvanometer at each end of the cable, an electrolytically insulated telegraphic circuit will be represented; through which signals may be transmitted from either terminal by uniting the poles of the battery at that terminal, which is best done with the aid of a key to which the poles are connected.

It need scarcely be pointed out that the *inner* tube or tubes of an electrolytically insulated cable may be of very slight thickness, and that the same observation applies also to the fibrous coatings. Doubtless there are many difficulties to be overcome before this mode of insulation can become practically available in telegraphy; but it is quite possible that, in the future history of this science-art, electrolytic insulation may be made to render good service.

FERRO-MANGANESE.

From "Engineering."

The supply of manganese for the steel-makers in this country has, during the present war, been a subject of considerable anxiety to every one interested in that important branch of metallurgy. We are dependent almost exclusively upon one small district in Rhenish Prussia for the supply of spiegeleisen, and this Prussian spiegeleisen is the only form in which metallic manganese is practically used by the steel-makers in this country. There is another kind of spiegeleisen accessible to us, but not actually in the market in this country, viz., the Franklinite spiegel from the United States, but its price does not in ordinary times make the importation of this material possible in competition with the Prussian spiegeleisen, and its qualities are therefore little known. Some trials which have been made with Franklinite iron in this country are said to have given unsatisfactory results, on account of a considerable percentage of zinc which was present in the material. It is known, however, that in America the Bessemer steel works actually employ Franklinite iron, and seem to be satisfied with the quality of the alloy. The probability, therefore, rests upon the assumption that the prime cost of American iron is too high to permit any regular trade in this class of pig iron to establish itself between this country and the United States. At the outbreak of the present war, and particularly during the time when an invasion of Rhenish Prussia was considered a probable result, the supply for spiegel to the steel-works in this country became very precarious, and the demand rising in consequence of the kind of panic which came over the limited circle of consumers of manganese alloys, the price of spiegel suddenly rose to nearly double its ordinary value. At the same time the moderate stock on hand in the different stores and steel-works in England threatened to run out and leave the steel-masters short of an indispensable raw material for the manufacture of steel. The comparatively insignificant trade in spiegeleisen, which h rdly exceeds 10,000 tons per annum, or a value of £60,000, as a maximum in ordinary time, has by this state of affairs become capable, when interfered with by unforeseen events, of checking seriously the production of about 200,000 tons of steel, and of putting a trade averaging about three millions per annum into a most precarious position. There was a time when the Government of this country was expected to interfere, and actually did interfere, with the prices of sulphur in Sicily, and, from equally powerful reasons, it might have been looked to for protecting the spiegeleisen trade from the injuries of the Continental war. Fortunately for us, such ideas of Government interference with trade no longer exist, and the steel-masters must look to their own resources if they desire to avoid any similar calamity, to re-occur perhaps with more serious consequences than those which were actually experienced at the beginning of the present war. Every steel-master ought to be able to make his own alloys of manganese, and thereby become independent of the uncertainties of trade, both with regard to the price and the quality of his products. It is not only a sudden increase in the price of spiegeleisen which steel-makers are exposed to, but it is also the inequality with regard to the composition and properties of the alloy itself when it is drawn from the blast furnaces of a distant country. The contracts made with spiegeleisen masters very often specially stipulate that the spiegel is to be made in winter, it being considered that the atmospheric condition in the cold season is more favorable to high quality. Other contracts exact the guarantee of a certain percentage of manganese, which is far above the average product of the spiegeleisen furnaces, and which, if conscientiously kept, must necessarily bring down the standard of the remaining portions which find their way into the English market in a more or less indirect manner, but which, after all, are used up principally in this country. In advocating the manufacture of manganese alloys by the steel-masters themselves, we desire to draw attention to the fact that this is actually the practice adopted in some of the most eminent steel-works on the Continent, and has been successfully carried out by them for some time past. M. Indica, the well-known manager of the Terrenoire Steel Works,

in France, has worked Henderson's process for making ferro-manganese; and the works of F. Krupp, in Essen, the Bochum Works, and several other Prussian steel-makers although in the immediate vicinity of the spiegeleisen district, have all adopted different methods of producing rich manganese alloys for the purpose of exercising a better control over the "temper" or quality of their high-class steel. A similar movement is now being made by some of the leading Bessemer steel-makers in this country, who are adopting Mr. Henderson's process for the manufacture of ferro-manganese. Mr. Henderson's patents are the property of the Tharsis Sulphur and Copper Company (Limited), of Glasgow, and this Company grants licenses to steel-masters for the manufacture.

At the last meeting of the Iron and Steel Institute, in Merthyr Tydvil, a paper was read upon this important subject by Mr. F. Kohn, which states that the cost of manufacturing an alloy of 20 to 25 per cent. manganese is about £7 per ton, independent of royalties, and that the market value of this material is correctly estimated by comparing the value of a mixture of ferro-manganese and ordinary hematite iron with the price of spiegeleisen of equal percentage. We do not agree with Mr. Kohn in this mode of calculation. The value of ferro-manganese for the steel-maker not only depends upon the absolute quantity of manganese, but within certain limits also upon the relative proportion which is held by the alloy. There are many brands of pig-iron in this country which require a rich manganese alloy when used for the Bessemer process, and the quality of Bessemer steel in general would be considerably improved with regard to great ductility and uniformity, if richer alloys of manganese were more freely employed by the makers than is the case at present. There is also the question of waste in the Bessemer converter, which appears to us to be very closely connected with the relative proportions of manganese and carbon in the spiegel, and which deserves a very careful consideration. The spiegeleisen used in this country contains on an average 8 per cent. of manganese and 5 per cent. of carbon. For every pound of manganese $\frac{5}{8}$ths of a pound of carbon are necessarily added to the charge when the spiegel is used. The quantity of manganese required for removing the surplus oxygen from a charge of Bessemer metal may be estimated at about $\frac{1}{2}$ per cent. of the weight of pig-iron in the charge with careful and experienced management of the converter and spiegeleisen furnace. Taking the relative proportion of carbon introduced with this quantity of manganese, we have $\frac{5}{16}$ per cent. of carbon in the steel, and this is very nearly the highest percentage admissible for rails and similar materials. For the softer qualities of steel, such as the ingots for weldless tyres and for boiler plates, this quantity of carbon is too high. To arrive at the desired result when no richer manganese alloy is at hand than this 8 per cent. "spiegel," the only course adopted is to blow more oxygen into the charge, so that a part of the carbon shall be combined with it when the spiegel is added. This apparently harmless artifice is a cause of great loss in every Bessemer steel-works. It is not possible to blow a surplus of oxygen into a Bessemer charge without forming a great quantity of oxides and silicates, which immediately pass into the slag, and are not subsequently brought back into the metallic state when the carbon and manganese are added. The quantity of metal which is in this manner entirely lost has no definite proportion to the quantity of oxygen, which at the same time will be left in the metal, in a form available for combining with manganese and carbon, and this is an unavoidable source of error and uncertainty. Under all circumstances, the loss of metal caused by the necessity of overblowing the charges is very considerable. There are not many records of comparative trials in this respect, but from some of the tabulated results collected at the time when Henderson's ferro-manganese was used in considerable quantities in Sheffield, it appears that, as compared with ordinary spiegel, the employment of rich ferro-manganese saved 5 per cent. of the metal in the converter when soft steel was made, and in some cases the difference appears to be greater still. From all these reasons it appears that the value of rich manganese alloys for the steel-maker has not hitherto been sufficiently appreciated, and that the present war will have given the impulse to a change for the better in this respect.

THE UTILITY OF RAILWAYS FOR WAR PURPOSES.

From "The Railway News."

The importance of railways for strategical operations has never yet been so clearly demonstrated as in the war between Germany and France, and it certainly could not have been carried on without them to anything like the same extent or with equal rapidity of action. In modern wars the possession of a railway is of much greater consequence than that of a navigable river or a highway on land, and as on the continent, with the exception of Russia, they are all laid down on the same gauge (4 ft. 8½ in.), they can be used alike by the locomotives and rolling stock of friend and foe. If we consider for a moment that there are at the present time more than a million of Germans under arms, of whom, after deducting the great losses in the battles already fought, at least 600,000 have advanced into the heart of France, some of whom are at this moment under the walls of Paris—if we consider further that it is not only in the enemy's country, where the inhabitants are naturally hostile, and by no means inclined to furnish food and supplies, but that it has till lately been occupied by large bodies of French soldiers, who have not failed to exhaust the resources of those districts—it becomes clear that provisions, forage, ammunition, and reinforcements—everything required, in short, for the success of the undertaking and the sustenance of the armies—must be sent up every day from the depots in the rear to wherever the front may be, and that the further they advance the greater the difficulty must become.

In the present instance the difficulty has been much augmented by political and geographical obstacles. Owing to the interposition of the neutral territories of Belgium and Luxemburg in the north, and Switzerland in the south, the only spot where the two belligerent frontiers touch is the Palatinate or Rhenish Bavaria; and therefore there is but one line of railway available—viz., that from Mannheim to Forbach and Metz, for the southern line through Strasburg has been rendered impassable by blowing up the railway bridge between that fortress and Kehl, on the German side of the Rhine. But this route has the disadvantage of passing under the guns of the great fortress of Metz—indeed, it goes through a part of the outworks of the fortification—and thus there is necessarily a break of continuity. The Prussians have, however, shown that their engineers are fully equal to the emergency of the occasion, for within a fortnight they have not only surveyed the country, but actually laid down a railway of twenty-five miles in length from the station of Remilly (to the south of Metz) to Pont-à-Mousson, including a temporary but safe railway bridge over the Moselle, by which not only is Metz altogether avoided, but a saving is effected of nearly twenty miles in distance. This wonderful exploit—for it is a feat unparalleled in the history of railway engineering—was achieved by the Prussian Royal Field Railway Corps, a separate organization, formed with admirable forethought in time of peace, and attached as a branch of the Royal Pioneer Battalion. The sleepers and rails were supplied partly by the Rhenish Railway Company and partly furnished from the stock on hand in the magazines of the Saarbruck State Railway; whilst fatigue parties of infantry soldiers and pioneers, assisted by a party of colliers from the coal mines at Saarbrucken were put in requisition for the earthwork of the cuttings and embankments.

"All stratagems are fair in war," but the Germans have discovered to their cost that some of those put in operation by the French cause them a deal of trouble and loss of valuable time. For instance, the French had on more than one occasion to retreat so suddenly, and, we may add, unexpectedly, that there was no time to destroy the railways, fill up the tunnels, or undermine the bridges. It was, however, found that in several places where they were obliged to retreat suddenly and abandon their railways, they had cunningly taken out the screws, but without removing the rails, which to a casual observer appeared to remain intact and be available for immediate traffic. Fortunately the discovery was made in time to prevent any accident, but the consequences might have been most disastrous, not

only as connected with loss of life, but by blocking up the road and causing delays when time was so precious. Orders have now been given to exercise the greatest vigilance and caution, and the Field Railway Corps now carefully examine every single rail of the permanent way, and report it perfectly safe for traffic, before any train is allowed to pass over the line. *Experientia docet.*

Two uninterrupted streams of traffic continue to flow on this line night and day in opposite directions—the one bringing fresh troops, ammunition, fodder, and provisions from all parts of Germany, and converging upon Manheim—and the other carrying back to Germany the wounded of both belligerents, thousands of prisoners, and the empty carriages and trucks, as well as the captured artillery, mitrailleuses, and other trophies of war.

The difficulties of working the traffic on a railway in an enemy's country are much enhanced by two elements that have to be taken into consideration. The drivers, engineers, pointsmen, station-masters, signal workers, and the other employes necessary for working the railway have had to be brought from Germany, and at first were of course utterly ignorant of the locality, the system of shunting and signalling, and the other minutiæ of detail in the working of the railway. They are all in the temporary employment of the Federal Government, and have been furnished most willingly by draughts from almost every railway in Germany; but having all worked under different systems, it required strong efforts and energetic and experienced managers to organize them into one body, and make them work well together. The other difficulty is that in most parts of the line there is but a single pair of rails laid down, and when one considers the enormous traffic that passes over them day and night, and the difficulty of arranging the departures of the two streams of trains so as to prevent collisions, it is really no wonder should there be delays, or even occasional accidents, though we must add that of the latter there have been hitherto none worth mentioning.

This war traffic, great as it is, has now been augmented to a still further extent by the order to bring up the heavy siege-guns and mortars required for the regular besieging of Strasburg and Metz, which are so strongly fortified that they can only be reduced methodically. This battering train, with its accompaniments of ammunition, shot, and shells, was sent from Magdeburg, Spandau, and other distant fortresses, and required the services of no less than a thousand special railway trains of thirty carriages each to forward them to their respective destinations.

And, finally, a further strain has now just been placed on the capabilities of the railway and the energies of the employes by having to convey the wounded and unwounded prisoners of MacMahon's army, consisting of nearly 100,000 men, to Germany, together with the captured 400 field guns, 70 mitrailleuses, 150 siege guns found in the fortress of Sedan, and all the Chassepots and other small arms of the prisoners, as well as many of the stores and other trophies of war taken from the enemy. These can only be sent by one line of railway as far as Mannheim; but on the other side of the Rhine this traffic is divided amongst the several lines according to the destination of the prisoners of war in the fortresses of Northern and Southern Germany. For this service six hundred trains are now required, and we are informed that they have worked and continue to work with an amount of punctuality and freedom from accident which would compare favorably with traffic carried on during a time of peace.

Since the announcement of the existence in York county, Pennsylvania, of a deposit of iron ore whence steel could be made directly, much interest has been felt in the operation of the Company organized to test this. W. W. Welkes, President of the Company, reports that the pig metal with the ore was put in the puddling furnaces. The latter being new, and not having the right kind of cinders, it was not expected that the results of the first heat would be satisfactory. But contrary to expectations, the ball, when put under the hammer, indicated that the operation was a success. The bloom was reheated and rolled into bar steel of a good quality.

There are now 12,000 windmills in constant use in Holland, for drainage.

THE MOBILITY OF FIELD ARTILLERY.

A correspondent of the "Army and Navy Gazette" (London) writes as follows on the subject of Field Artillery:

Few people will be found bold enough to deny that amongst the *desiderata* for field artillery mobility may be assigned a high place. To so great an extent has this been recognized by the highest authorities that Gustavus Adolphus organized a flying artillery of leather guns, which, though far inferior in range and accuracy to the other ordnance in use at the time, left nothing to be desired as to lightness and rapidity of movement. Marshal Marmont and the Great Napoleon most impressively assign to mobility the second place among the qualities necessary to the efficiency of artillery in the field; and in our own army the Horse Artillery have been of late supplied with a gun known to be far inferior in shooting to that used by the field batteries, but which possesses the advantage of less weight both of guns and ammunition. As to the advantages derived from the leather guns of Gustavus Adolphus, no one who studies the history of his victory at Leipzic can well deny that even loss of range and accuracy was more than compensated for by celerity of movement. Napoleon's favorite operation, that of suddenly and unexpectedly concentrating an overwhelming artillery fire on a given point of his enemy's line, was one demanding in the highest degree rapidity of movement, and the disadvantages of slowness are aptly illustrated by the fact that in executing this manœuvre at Wagram, 15 out of 60 French guns were disabled before they could unlimber; the greater portion of this mass consisting of foot artillery (which we at present term field batteries), and being in consequence compelled to advance into action at a walk. Now, as most of your readers are doubtless aware, the field artillery of the British army is divided into two classes, known respectively as horse artillery and field batteries, the former of which is intended to act principally in concert with cavalry, the latter with infantry. To secure sufficient rapidity of movement to the first of these classes, the gunners are mounted on horses, with the exception of two, who sit on the gun limber; and it may be fairly said that no nation in the world possesses a better organized and equipped arm than the horse artillery of the British army. Our field batteries are also in many respects most admirable; but in their case an extraordinary anomaly exists. While they are carefully instructed in a system of regimental drill, which involves mounting the gunners and frequently moving at a trot, they are unable to carry out either of these very desirable objects when working with other troops as if on actual service. This peculiarity arises from the fact that only one non-commissioned officer per gun is mounted on horseback, and the rest of the gun detachment, with the exception of two who, as in the horse artillery, are carried on the gun limber, have no means of accompanying the gun, should it move out of a walk, unless by mounting on the ammunition wagons; but this, which is the system laid down for regimental drills, is strictly forbidden on service, as the wagons are never, if possible, to be exposed to the enemy's fire. Thus the pace at which a field battery can actually move is determined by the speed which can be obtained from its gunners on foot without exhausting them, for every soldier knows the importance of the first few rounds being quickly and accurately delivered, a result entirely unattainable with men blown and exhausted after a run of perhaps half-a-mile, probably over rough and uneven ground. The obvious idea which first presents itself to the mind of a civilian is, "Turn all your field batteries into horse artillery, and they will then be available to act either with cavalry or infantry." Unfortunately, one word puts this excellent and simple remedy entirely out of the question—that word is, expense. A battery of horse artillery requires more horses than a field battery, and horses, especially just now, cost money. It remains, then, for us to devise some other means of carrying a sufficient number of men at a trot to enable us to work our guns efficiently. Let us see if this problem has not been already solved. The Bengal horse artillery used to mount gunners on the off horses of the gun teams, and both horse and field batteries of the same army carried two on seats fitted to

the top of the axletree boxes. The Norwegian, Swedish, and Danish armies are without horse artillery, but their field batteries carry men on the off horses when required to move rapidly. The Austrians mount some of their gunners on a species of saddle on the trail of the gun, and the Prussians carry men on the axletree seats. The French, indeed, do not provide any of these means of carrying their gunners, but they are far less chary than ourselves of exposing their ammunition wagons, which, of course, enables them to make use of them as vehicles for the men ; and most people, moreover, will allow that late events should render us cautious in adopting French principles, whether in the administration or the tactical instruction of our army. We see, then, that other nations have recognized the necessity of mobility in their field batteries, and have adopted various means of obtaining it. The committee which lately decided on the artillery equipment for India introduced, among other valuable improvements, axletree seats for two men per gun, but, although this equipment is likely *in time* to be supplied to batteries on home service, the elastic nature of the period so described is so well known that the question naturally arises, whether something of the sort cannot be added to our present gun carriages. To this the answer is, yes. Seats can be fitted to the present pattern of axletree boxes, which will be quite capable of carrying two men, and these with the mounted non-commissioned officer and two, or, if necessary, three, limber gunners, will afford a sufficient detachment which can always be carried wherever and at whatever pace the gun may be required to go. One artillery officer in particular has made experiments with a seat of his own contrivance, with the most satisfactory results. It appears to be not only perfectly safe, but an easier and pleasanter seat than the gun limber. In fact, many who have tried it declare that they would sooner ride either far or fast on it than on the latter. The question being thus solved, what prevents seats of this or some similar pattern being applied to all our field battery guns? The bugbear, no doubt, which has always interfered with the mobilization of field batteries in our service is the fear of their "galloping" and "aping horse artillery," but it is time that such unworthy and puerile jealousies should cease or be ignored. The point to aim at is, not the empty swagger of galloping past at reviews, and impressing the minds of the fairer sex by an appearance of dash and rapidity, but to place our otherwise excellent field batteries on such a footing that they may be able to perform their duties in conjunction with the infantry as efficiently as our unrivalled horse artillery can assist the cavalry. Numerous instances may be mentioned where the mobility of field artillery has conduced largely to success, and, on the other hand, where the want of that quality has hampered and crippled the efforts of generals and armies ; and surely in the British service, above all others, smallness of numbers should, as far as possible, be compensated for by perfection of equipment and organization.

BELGIAN COAL.—The exports of coal from Belgium in the first six months of this year amounted to 1,843,414 tons, against 1,640,823 tons in the corresponding period of 1869, and 1,759,712 tons in the corresponding period of 1868. France took 1,772,138 tons of Belgian coal to June 30, this year, against 1,573,169 tons in the corresponding period of 1869. The commercial relations of Belgium with France are now, however, greatly disturbed by the war, and the Belgian coal trade has been drifting in consequence into a state of dulness and depression.

AUSTRALIAN TELEGRAPHY.—It is interesting to note, in connection with submarine cables about to be laid off the Australian coast, that it has been ascertained that the bed of the Gulf of Carpentaria is composed of mud in which a cable would bury itself, so that it would be protected from any adverse influences, climatic or otherwise. Submarine routes between Java and Australia are not considered to present any serious difficulties.

THE total value of the river commerce of the towns and cities on the Ohio is estimated at $715,000,000 per annum. In this vast sum Cincinnati figures for $169,506,000.

WAR AND EDUCATION.

From "The Builder."

War topics naturally occupy public attention almost exclusively. Literature has taken a fiery tinge. The daily journals can find no room for subjects such as, at other times, would command large type. For a few days "the Row" was paralyzed; and the weekly issue of new books came to a stand-still. In art, in industry, in speculation, every one is pausing for a moment, aghast at the great events which are taking place under our eyes, or waiting for the next telegram.

Without overstepping the prescribed limits of our own columns, or invading the provinces of the periodicals especially devoted to military science, or to military history, there is much which the present campaign forces upon our attention, which lies on ground familiar to our readers. Strategy, tactics, and descriptive literature, we altogether pass by. But the war has already taught, and must yet teach, lessons of the utmost importance, of a more general nature, as well as some of a nature especially germane to our columns. The architecture of war, or the relation of military science and practice to the works of the builder, has received ample and most important illustration. No less have the mechanics of war been exhibited under a new light; and even of more importance, as deeper and wider in their scope, are those loud and eloquent lessons which speak of the connection existing between the educational state of a country and its military prowess and national defence. We have long seen that national wealth would shortly be admitted to be little more than a fraction of the educational state of a country. It now almost seems as if the same might be said of national existence.

With regard to the architectural lessons to be derived from the war, they are, as we write, loud and repeated, although it may well be said that the most signal of them all is as yet unpronounced. In a word, the idea is this. The importance of fortresses is greater than ever. The fortification of towns and cities is a cruel mistake—that is to say, their fortification by walls and ramparts. The fortress that is of vital importance in the stern chess-game of war is a military place pure and simple—a nest for soldiers, placed so as to command a defile, a river, pass, or railway; casemated so as to give cover to its defenders; built on the live rock, so as to set the art of the miner at defiance; provided with water by wells and springs pierced within the very heart of the citadel, so as to be incapable of being cut off by the enemy; walled according to the best methods known to military science, and armed with heavy guns, which, if they attain the at present largest size of 600 pounders, will have four times the calibre of the most powerful siege guns that is yet practicable to place in the trenches. A properly provisioned and munitioned fortress of this kind, containing a garrison proportional to the strategical importance of the spot, may be made virtually impregnable, except by famine. With our late improvements in the preparation of food, with the meat extract of the Liebig Company, the Swiss condensed milk, the new German sausages, the best biscuit, and the most carefully-stored grain and flour,—such a fortress might be easily provisioned for three years. Had Metz and Strasbourg been fortresses of this kind, and in this good order, it is more than problematical whether a cautious strategist would have ventured a march on Paris.

On the other hand, the cruel error of attempting to combine city and fortress is pregnantly illustrated in the case of the two great arsenals of Lorraine and of Alsace. Fortified, in his time, by Vauban, and since materially strengthened, furnished with that best of defences, a wet ditch, or series of ditches, in which the water can be raised or lowered by the defenders, these cities were intended to form great offensive centres for warlike operations. The idea that they would have to resist any formidable invasion, is one that no Frenchman would have allowed himself to entertain for a moment. But under actual circumstances, not only has the presence of the large civil population involved suffering of a magnitude which even enemies shrink from inflicting, but the absolute military influence of the presence of so many non-combatants has been in every way prejudicial to the defence. A large garrison is required,

greater labor is entailed on every soldier, the points of attack are more numerous and more wide apart, and the provision that might prove ample for the soldiers, shrinks rapidly before the consumption of the inhabitants. The speedy acquisition of Metz has not been a point of strategic importance—that of Strasbourg has ; as the railway communication across the Rhine is impeded by its guns. Thus the terrible expedient of bombarding the town itself lay, according to the admitted laws of war, at the discretion of the general commanding the besiegers. It is true that the King of Prussia ordered a procedure which would lay in ashes a town of German origin and history to be suspended, as a striking contrast to the vindictive destruction of Kehl by General Uhrick, and to the malignant melodramatic shame of the shelling of Saarbruck. The point we wish to bring out is, that while the purely military fortress of Phalsburg has held out, to the honor of its garrison, and as an appreciable item in the defence of the country, the mixed character of Strasbourg has caused a great national disaster. Even if the citadel should hold out later than the city, the military loss will have been more, and the military defence weaker, than in the case of a simple fortress, while the fact of drawing fire on a city of 70,000 inhabitants (the main use of the walls of Strasbourg) involves at once a political evil amounting to positive disaster, and an amount of useless human suffering most painful to contemplate.

In fact, the breadth and precision of the line drawn between combatants and non-combatants is not only a redeeming feature of modern warfare of the utmost importance, but it is one on the preservation of which depends the answer to the question whether war, with its new and terrible means of destruction, shall or shall not imply total extermination. Any confusion of the line of demarcation between regular hostilities and murder can lead only to the great increase of the latter. In the confusion of character caused by walling in civilians and soldiers together, nothing is more probable than such a mingling of all occupants and defenders in one indistinguishable mass, as shall lead to total extermination on the success of the siege. And it must be borne in mind that it is a military axiom that the resistance of any place that is not relieved is only a question of time.

The lessons thus terribly taught us have this direct home application. We should make Pembroke our great arsenal, rather than either Portsmouth or Plymouth. At Pembroke the severing of the military and the civil element is and can be more distinctly effected than at any other place of naval importance in the United Kingdom. The few streets of workmen's houses that surround the dockyard might be swept away without any compunction. The immediate defence from the promontory crowning the head of the bay is good. The dockyard is situated at the head of a noble arm of the sea, or inland salt lake, the narrow entrance to which is capable of admirable defence. Within lies the Stack Rock, now fortified, which alone would sink any foeman within the gap. In the harbor the whole navy of England might ride in safety ; and on sailing, a vessel is in the open sea in half an hour. In all our systems of defence these great peculiarities should be borne in mind. Very few spots in the world are so fit for a naval centre as Pembroke.

With regard to the mechanics of war, we do not wish to enter at this moment into the military questions of the relative value of the several arms. Our own attention has been long and not unprofitably turned to the subject ; and our Snider rifle is a far more effective instrument than either the clumsy Chassepot, or the heavier, but somewhat better finished needle-gun. It is likely, however, that the latter weapons may better bear being knocked about, and certainly our own rifle requires to be used by a man more handy with his fingers than is needful in order to turn round the bolt-shaped handle of either of the other weapons. But the great mechanical feature of the war has been the service rendered by the railway system. The importance (to which we have just alluded) of any given fort, depends, now in very great measure, on the fact of its command of a railway line. Metz has been turned, in this respect, by the admirable expedient of constructing a temporary line of railway. The advance of the German host has been made at a rate hitherto without any precedent, by the service of the German railways. Distance, in strategy, is measured only by time, and distance has been reduced to a

degree which Von Moltke has precisely calculated, but of which we can only say that it must be less than the half of that reckoned in any former calculations. Other mechanical appliances have been pressed into the German service. Traction engines, the enormous power of which we are only beginning to realize in this country, are employed to move heavy guns into position. And captive balloons, although to our surprise they do not seem yet to have been employed, are in preparation. The admirable service of a secret underground telegraph is said to have been discovered, and cut, between Strasbourg and Metz. The field telegraph, for tactical purposes, has, no doubt, been organized as carefully as is now the case with that of our own Royal Engineers. Of the pontoon service we have heard but little, but it is, no doubt, efficient. The increased venom of the engines of death has not been such as to give great advantage to either side. But the command of the railway system has rendered possible an invasion in mass, which the preparation and the provision of border fortresses, properly proportioned, armed, and provisioned, must have, to say the least, materially delayed.

While we can thus already see, with no indistinct vision, some of the lessons which the statesman and the military architect and engineer cannot fail to draw from the terrible experience of our French neighbors, there is yet another which comes with more momentous force to ourselves. We have more than once insisted on the importance of bringing up our national education—in other matters than Latin and Greek—than reading, writing, and arithmetic—or even than the higher mathematics—to the level of more educating nations. We know from the reports of our own Education Commissioners, as well as from those of foreigners, that we occupy all but the lowest place in Europe in this respect. In the rapidly evaporating Roman States, indeed, and wherever the priest has his own way, thick and utter darkness is the object successfully attained by what is called education. Next to priest-ridden countries, come professor-ridden countries—or those in which competitive examination is adopted as a test of merit. This has been especially the case in Austria, which is called, *par excellence*, the *pays à l'examen*—an examination country. We are at present cheerfully and contentedly engaged in promoting ourselves from the first of these categories to the second. In France, while very much of the rural part of the country may still come under the sacerdotal extinguisher, there is a great amount of scientific, practical, and industrial education. But throughout the entire country the schoolmaster has been handicapped. A central impulse has been given which every lyceum or school has been compelled to obey. The first object of the entire and severe course of schooling prescribed to the French boy was to make him a good Imperialist. Hence the terrible inability to look fact in the face, or to serve or save the country, of which each day furnishes such disastrous truth.

Now, when we see this one-sided or no-sided education brought into contact with the broad and paternal culture of Germany, the results are even more striking in war than in peace. Of all the Germans round Metz, there was hardly a man who had not an idea of the plan of the campaign. He knew the object of that great silent strategist who had moved king and princes, and *corps d'armée*, like pawns on the board, though he might little understand each individual move. He intelligently received and faithfully obeyed orders. He regretted having to leave his home; but, meantime, his life was at the service of his country.

The French army, judging from their own reports as well as from those of English visitants, were in the very opposite position. Not a map of the seat of war was to be seen. Even the officers pent up in Metz thought that they were brought to the front to defend that city; the soldiers thought nothing, except that they were betrayed. They formed a class apart from the officers, though the latter rise from the ranks. They mistrusted them, and even fired upon them, and if we can believe but the half of the tales of plunder, conceited ignorance, and utter carelessness that we hear of marshals, generals, and even subalterns, driving luxuriously to war, as to a promenade, in the rear of their regiments, we can hardly wonder at it. Thus the educated and uneducated army, the armed nation, and the paid machine, came in collision. With what result?

Since the introduction of mercenary

troops into warfare first spread from the example of the ever-contending Italian States, the great question of the natural relation between the army and the nation, between the State and its armed means of defence, has not only been a study for the statesman, but a problem involving very shifting and inconsistent elements. Into that long and interesting history it is unnecessary here to enter. The last case of the problem has now received a solution so decisive that none who regard the matter from the scientific point of view can hesitate as to the import of the facts.

The two opposing forms in which military defence is organized (or is thought to be organized) by modern civilization have been brought face to face. The balance has never for an instant wavered. And although in the scale that has kicked the beam it is easy, after the event, to recognize certain elements of failure, that may be thought foreign to the question of principle, it may yet be seen that, for the introduction of these foreign and disastrous elements there has, practically, been found ample room in one system, and little or none in the other.

On the one hand, we have seen a professional army, reckoned, less than three months since, not only the finest in the world. but the finest that had ever been seen in the world. This army was permanent, mercenary, – raised, indeed, not by voluntary enlistment, but by conscription, yet possessing an *esprit de corps* that very rapidly transformed the conscript into the soldier. To the perfection and the brilliancy of this great military engine the resources of a nation of thirty-seven millions and a half of people were freely consecrated. It was the first object of the French Budget, the chief pride of every Frenchman. Not only was the army petted, not to say pampered, as the *elite* of the nation, but it was formed on the principle of giving disproportionate value to picked corps, as compared with the great arm of most great generals, the infantry. Such was the prestige of this army, such the amount devoted to its production and maintenance, to its terrible and secret artillery and to its brilliant guard, cuirassiers, and "dusk faces with white silken turbans wreathed,"—that we are told that an English Cabinet Minister declared his belief that it would be in Berlin within three weeks from the time that its leader threw down the gauntlet.

In opposition to this *chef d' œuvre* of the prætorian system was an army of altogether different organization. It was one formed on the old-fashioned principle that every man is the natural defender of his own hearth, and that, in case of need, he is bound to pay, not only in purse but in person, the cost of that defence. Having known what invasion was, and having drained the bitter cup to the very dregs, the Germans betook themselves to prepare a mode of prevention, with that same patient, steady, unflagging, undemonstrative, successful energy which a phlegmatic and resolute race have brought to bear on so many difficult problems of her vital interest. If the nation could but be prepared to rise in arms as one man, or rather as a succession of men, advancing decade after decade, the standing army that they would require would be only such as was needful to keep up the *cadres* of the organization, and to educate the lads who, year after year, arrived at the age of military discipline.

So admirably was this great system ordered, so ample were the preparations of the heavy and costly material of war, so prompt and effective the means of transit, that at the first great call, when the wolf was indeed coming, the mighty engine started without a check. Peasants and nobles, learned men, wealthy men, busy men, walked rapidly and quietly to their nearest depot. They came out armed and in uniform, in bodies that flowed, like contributing rivers, to the frontier.

The one grand advantage supposed to be possessed by the standing army was its instantaneous capacity for movement. The trumpet had but to be blown, and the troops were on the march. For the concentration of the citizen army, on the other hand, a certain delay was unavoidable. It entered into the calculations of the strategist. Each day, from the date of the order to arm, brought two army divisions to the standard. But it so turned out that the machine that was to be ready for instantaneous service was out of gear. The professional army did not work, and the citizen army did.

It does not follow that a standing army is necessarily a source of private plunder. But it is no less certain that the prætorian troops, which were thought the finest in

the world, have thus failed in the hour of need. It cannot be urged, henceforth, that the vast expense of a standing army gives a reliable safeguard to a great country. The evidence so far as it goes is the other way. And it is clear that a well-ordered citizen army can be raised, and armed, and sent to the point of danger with a celerity hitherto undreamed of.

We cannot but believe that the German system will, for the future, be the European system. That there will be many to deprecate its introduction into this country we do not doubt. It is a strong characteristic of the Englishman to resist improvement to the last hour, and then to effect it with more haste than good speed.

But apart from the domestic question, we trace in the grand German crusades an augury for the future education of the world. To take every lad, before either stature, or gait, or habit, is formed (often boorishly formed), and, as soon as he is able to endure a certain amount of hardship without checking his growth, to give him an education at once physical and moral,—to teach him to march, to ride, to fire, daily to pass many precious hours in the free open air, and even more than this, —to give him habits of order, of precision, of cleanliness, of truth ; to teach him how to obey, and thus how to command ; to tell him practically that he is a citizen, and that he has duties that he owes to his country ; and to redeem him, at this critical age, at once from idle frivolity and from the prematurely contracting pursuit of gain,—this will be a gain for the future generations of Europe not unworthy of the blood that has been shed to acquire the lesson. Nor is there any reason why the education of the soldier citizen of the future should be physical and martial alone. The State is responsible for bestowing the best cultivation on the youth whom she organizes as the seed-plots of her armies. The finest education given in this country is (or rather was before recent changes) that of the Royal Military Academy at Woolwich. Five terms of that wholesome discipline converted the pale and over-worked schoolboy (for all had to work in order to pass the barrier of Chelsea) into the vigorous, healthy, well-taught, reliable soldier. The battle of Sedan means that we shall not allow Switzerland and Germany to remain the only free countries that educate their youth for all the duties of grave and martial manhood. It means that every boy in Europe shall, sooner or later, be taught how best to become a man. The cad will, under the good influence of the drill-sergeant, attain some title to self-respect, in learning to respect his superiors. "Peace it bodes, and a quiet home, and successful rule, and due supremacy ;" and we may hope that peace will be more likely when war is no longer a trade, but is regarded as either the "worst of crimes or the most sacred of duties."

CENTRALIZING MOTIVE POWER.

By J. RICHARDS, M. E.

From "The Journal of the Franklin Institute."

The most important element in human industry is the employment of the forces of nature to produce effects beyond the scope of manual effort. To convert the crude materials of nature into such forms as will give us shelter, food, clothing, comfort, and pleasure, is the business of human life. If the reader will glance around him, no difference where he may be, I doubt whether he will be able to find a single article, great or small, of human production, that does not in some degree owe its origin to the employment of physical force ; and perhaps not one that is not, directly, or indirectly, the product of steam power. It forms an interesting problem. The paper on which we write, the pen, even the modern pen stem, the paper on the walls, every nail, the clothes we wear, the buttons, even the gas that furnishes the light, can be traced back to the steam-engine, or other motive power, that has been the main agent in its manipulation from the crude materials of nature.

It would be, further, a safe proposition to say that, next to human life itself, the great auxiliary of natural forces is to us the most important of earthly matters, so intimately are they connected with our

civilization and welfare. A thing, then, so important as motive power should command our continual and earnest consideration. Its economy and safety should be the most important of all questions in science. Whatever contributes, even in a minor degree, to its improvement should be recognized as of the highest importance, and take precedence over other discoveries and inventions in the rank of its great importance.

The improvement of the steam engine has, no doubt, of all other mechanical subjects, received the greatest amount of scientific attention, but it has, without doubt, been too much confined to various modifications in its mechanical construction with a view to special adaptation, and such economy as could be attained by improvements in steam generators, furnaces, and valve movements. The great question of *aggregated* or *segregated* sources for power has not (at least in this country) received much attention. The question of localizing and distributing motive power bears directly upon the two greatest questions involved: the cost of power and its safety. As affecting these conditions, it is proposed then, in a brief way, to present some views as to what might be gained by centralizing motive power in manufacturing districts and distributing it to be used by the manufacturers as we do gas or water. The first thing, aside from physical practicability, to be considered, is a proper medium for transmitting accumulated force in a way to be graduated, measured, and carried to a distance. This medium nature has provided in our atmospheric air, freed from a single fault, in fact impregnating our systems and essential to life. It is without money and without price. Governed by the laws of gases, it has all the properties and fulfils all the conditions of steam for a common engine, except that of lubrication. It is not explosive, it is free from danger; after use there is no residue, it can be discharged in any room, conducing to its comfort in either winter or summer. It is so subtile that it can be carried to any distance through innumerable angles without diminishing materially the original force; and we must consider it strange to see the attempts recently made, in Germany and elsewhere, to transmit power by means of ropes and pulleys, through long distances, instead of using compressed air for the purpose. In contrasting, or in considering different means of transmitting power to a distance, we find as the most important conditions: first, the loss by friction; second, durability; and third, first cost—we mean, of course, after demonstrating the practicability. Air has already been extensively employed for propelling machinery and in raising liquids, after being compressed by mechanical means. Its flow through pipes and the valves of engines and pumps has been demonstrated, and is, as we believe, determined by fixed formulæ. Machinery for compressing it, is well known as either the blowing engine or the hydraulic apparatus; so that perhaps the only things to be considered in suggesting a system of concentrating power at one point and distributing it to consumers, are the pipes for conducting it, and the saving that would be effected by such a system.

The difference in cost of generating 1,000 horse-power by a single condensing engine, favorably located, when contrasted with the cost of producing the same power with forty non-condensing engines with 25 horse-power each, is we will assume, as two to one, an assertion that is undoubtedly a safe one, when we consider the cost of attendance, room, wear, and fuel. Supposing that the cost of generating this power is in one case $50 per horse-power per annum, and in the other $100 per horse-power per annum, we have a saving representing the sum of $50,000 per year in 40 of our shops, supposing the amount of power used to average 25 H. P. each; or should we assume that twenty steam engines of 50 H. P. each, would cost proportionately compared with the large one of 100 H. P., we should have this saving represented in twenty manufacturing establishments using that amount of power.

This sum would lay conducting pipes through almost any of our manufacturing districts, to the extent of 1,000 H. P., and we would in a single year pay for the piping, and in another year pay for the compressing machinery, while either would last for twenty years.

The saving in cost, although no doubt the question that would have most to do with the inaguration of a system of centralizing and distributing power, is but one out of many involved. With a "pneumatic main" laid through the streets of our manufacturing districts, and each

manufacturer taking off his power through a meter, we would gain not only in economy and convenience over local steam power, but obviate nearly all that is objectionable in it. The danger from boiler explosions would be gone. The smoke from steam furnaces would be avoided, the heat and danger from fire would be avoided. The room would be saved, the water rate would be saved. The engine would not freeze in the winter. The cost would be as the amount of power used, which could be varied with the state of business; or a change in the capacity of the motive power could be made at a trifling cost.

May we not look for the next great innovation in motive power to consist in centralizing it and distributing it by means of pneumatic apparatus?

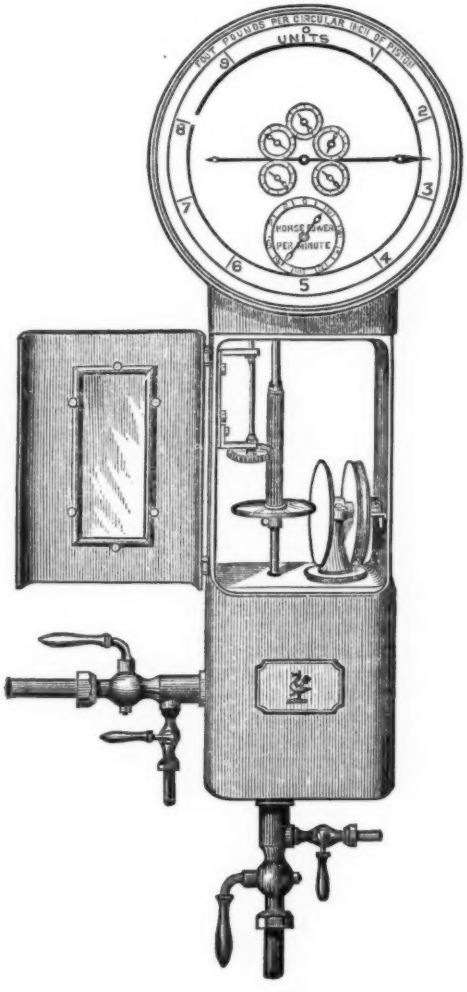
ON A STEAM POWER METER.

By Mr. ASHTON.

From "The Engineer."

The extent to which the employment of steam power in our varied industries, and as furnishing means of locomotion, has become a necessity, and the desirability of attaining the utmost economy in the consumption of fuel, render it a matter of the first importance to be able readily to ascertain the exact amount of power developed by steam machinery in a given time. Hitherto approximate estimates founded upon the results of isolated tests and experiments, or calculations based upon the diagrams produced by ordinary indicators, have furnished the sole means for the ascertainment of the duty of, or, in other words, the power developed by steam engines in all cases where the said power has been subject to variations. These indications have been taken at intervals of at least one day, and in most cases of a much longer period, and have simply been registrations of the amount of power developed during the one stroke, or the two or three strokes performed by the engine during the time of indication, the great variations in the load upon or the speed of the engine, and in the pressure of the steam occurring in the intervals between the indications being practically disregarded; and even when a correct diagram has been obtained, the power developed during the indication has and can only be ascertained with any degree of exactness by a tedious process of measurement and calculation. The patent power meter and continuous indicator, on the contrary, not only measures the power developed during a single stroke of the engine with as great a degree of exactness as the best indicator hitherto in use, but also registers the result of the said measurement with as great a degree of exactness as it is measured, thus avoiding the errors arising in the operation of measuring and calculating the area of the ordinary diagram; and, what is of more consequence, this measurement and registration are effected with reference to each and every stroke of the engine, and furnish a means whereby a correct judgment may be formed as to whether there has at any time been a want of due observance of economy in the use of fuel, or whereby the comparative merits of different kinds of fuel or of lubricants may be tested. In cases where power is supplied to tenants this instrument furnishes the only means whereby the power so supplied may be accurately measured. And in the case of marine engines in a rough sea it is the only instrument that can give any reliable information as to the power exerted by the steam engines, inasmuch as it is frequently impossible to obtain constant diagrams by the ordinary indicator during a whole voyage across the Atlantic. The steam power meter and continuous indicator, as its name implies, shows at all times the measure of the power developed by the steam engine to which it is applied, and registers the aggregate of that power during any required period of time. The instrument consists of a small double-acting indicator cylinder, 1½ in. in diameter, each end of which is connected by means of a pipe with the corresponding end of the steam engine cylinder. These connections are made as short and direct as possible. The piston-rod of the indicator carries a long-toothed pinion, which revolves loosely on the rod, but is held endwise between two screw collars. This

gears into a toothed wheel, which is connected with and drives the indices. At the lower end of the long pinion, and fixed to it, is a light wheel, called the integrating wheel, having a smooth rim with a rounded face. To the upper end of the piston-rod is attached a spiral spring, which offers a resistance to the free movement of the piston in its course from the middle to either end of the indicator cylinder; on a short horizontal shaft is mounted a circular disc, whose face is



constantly, but not forcibly, pressed against the rim of the integrating wheel; this is effected by means of a light flat spring, bearing against the end of the shaft on which the disc wheel is mounted. A small cog wheel is also keyed on the disc shaft, and is connected by a rack or any other suitable means to the cross-head or other convenient reciprocating part of the steam engine. Or a small pulley may be keyed on the disc shaft, round which is wound a cord, whose two ends are at-

tached to the cross-head or other convenient reciprocating part of the steam engine, being carried thence round loose pulleys above and below. By either of these means the reciprocating motion of the steam engine is converted into a rotary motion of the disc, acting in alternately opposite directions. When there is no pressure on the piston of the steam engine, and accordingly none on the piston of the indicator, the integrating wheel is so adjusted that the point of contact of its rim with the disc shall be at the centre of the disc, that being the zero point of the instrument. When the pressure of the steam is admitted so as to act on the piston of the indicator the integrating wheel traverses in consequence from the centre towards the circumference of the disc, the distance traversed being proportionate to the pressure of the steam on the piston. Suppose, now, the crosshead of the steam engine, and with it the disc of the instrument, be moving, such motion will be communicated by the disc to the integrating wheel, and through it to the indices. The motion so given to the indices during this stroke of the steam engine is proportionate to the pressure of the steam on the indicator piston during that stroke. Let it now be supposed that the stroke is finished and a return movement is commenced, the disc will now rotate in the opposite direction, and if the steam acting upon the piston were pressing in the same direction as before, the integrating wheel and indices would necessarily go backward. If, however, the steam, as is usual, acts on the opposite side of the piston when the piston's motion is reversed, the integrating wheel will be moved to the opposite side of the centre of the disc, so that the integrating wheel and indices will be moved in the same direction as before, and the quantity of motion through the receding stroke of the engine will again be proportionate to the pressure of the steam on the piston during that return stroke. Here, therefore, is provided a means of moving the indices during each stroke of the engine through a space proportionate to the sum of the moments of pressure exerted during that stroke, or, in other words, a means of indicating the amount of power developed during that stroke. The relative proportions adopted for the several working parts in the present instrument are such that each division on the dial represents 1,000 ft. lbs. of duty for each circular in. of the piston of the steam engine. These proportions may be varied. Thus the parts of the indicator may be so arranged that the readings on the dial shall represent the number of horses' power given out during any required period of time. By closing the tap connecting one end of the indicator cylinder with the corresponding end of the steam engine cylinder, and opening the small drip tap to admit air freely to the disconnected end of the indicator cylinder, the indicator is thus rendered single-acting, and will show the manner of working and the amount of work done by one end of the steam engine cylinder alone. By opening the closed taps and closing the open ones the indicator is reversed, and the manner of working and the amount of work done by the other end of the steam engine cylinder ascertained. In the case of a non-condensing engine the integrating wheel would not return to the centre of the rotating disc during the back or return stroke of the engine by a distance proportionate to the back pressure opposing the motion of the steam engine piston, the effect being that during the return stroke the integrating wheel and indices would be wound back by an amount of motion proportionate to the loss of power by back pressure. Also, if the valves of the engine are opened or closed too early or too late, the integrating wheel will be seen to move backward at the beginning or end of each stroke, thereby showing work undone by an amount of motion proportionate to the loss of power by such "cushioning," or too late admission of the steam or too late exhausting of it. The instrument can be so constructed that paper diagrams may be taken indicating the action of the steam in each end of the steam engine cylinder, or in both ends conjointly.

Formula for showing the relative connection of the dimensions of the various parts of the power meter.

Let w = the weight in pounds required to distend or compress the spring 1 in.
" d = diameter of indicator cylinder in ins.
" D = diameter of integrating wheel in ins.
" L = number of teeth in the long pinion.
" M = number of teeth in wheel geared in long pinion.
" N = number of teeth in worm-wheel or first index-wheel.
" x = diameter of driving pulley on disc shaft.

Then d^2 = the area of the cylinder in circular inches, and $\frac{w}{d^2}$ = the pressure in lbs. of steam per circular inch on the piston to distend or compress the spring 1 in. One revolution of the disc with the integrating wheel 1 in. from its centre will drive the integrating wheel $\frac{2}{D}$ revolutions. Then $\frac{2}{D}$ of $\frac{l}{m}$ of $\frac{1}{n}$ = the parts of one revolution of the index for one revolution of the disc, that is $= \frac{2\,l}{D\,m\,n}$. And because $\frac{w}{d^2} \times \frac{3.1416\,x}{12}$ = the foot-pounds represented by one revolution of the disc per one circular inch of piston $= \frac{3.1416\,w\,x}{12\,d^2}$. Therefore, $\frac{3.1416\,w\,x}{12\,d^2} \times \frac{D\,m\,n}{2\,l} = \frac{3.1416\,D\,m\,n\,w\,x}{24\,l\,d^2}$ = foot-pounds per one revolution of index, or assume one revolution of index = 10,000. Then $\frac{3.1416\,D\,M\,n\,w\,x}{24\,l\,d^2} = 10{,}000$, and $x = \frac{240\,000\,l\,d^2}{3.146\,D\,m\,n\,W} = \frac{76394.194\,l\,d^2}{D\,m\,n\,W}$. Therefore each unit on the dial of the power meter represents 1000 foot-pounds per circular inch.

To find the work done by an engine in any given time.

Where d = the diameter of the engine cylinder in inches, n = the number of the meter index at commencement of time n_1 = ditto ditto ditto at the end of that time. Therefore, $1000\,(n_1 - n)\,d^2$ = foot-pounds.

To find the work done in horse power.

Where m = number of minutes elapsed between the times of reading the meter and 33,000 feet pounds represents the duty of one horse per minute. Then $\frac{1000\,(n_1 - n)\,d^2}{33{,}000\,m} = \frac{d^2\,(n_1 - n)}{33\,m}$ = load in horse-power.

To find the quantity of coal consumed per horse per hour.

Let H = horse effect of the engine.
" h = hours during consumption of the coal.
" w = the weight of the coal in lbs.
And $\frac{w}{h}$ = the number of lbs. of coal consumed per hour.

Also

$$\frac{1000\,(n_1 - n)\,d^2}{33{,}000 \times 60\,h} = H = \frac{(n_1 - n)\,d^2}{1980\,h}.$$

And because $\frac{w}{H}$ = lbs. of coal consumed per horse per hour, therefore, $\frac{w}{h} \times \frac{1}{H} = \frac{w}{h}\,\frac{1980\,h}{(n_1 - n)\,d^2}$ or to $\frac{1980\,w}{(n_1 - n)\,d_2}$ = consumption of coal per horse per hour.

RANSOME STONE.

From "Engineering."

In front of the Temple Station of the Metropolitan District Railway two large areas extend on either side of the entrance to the booking-office, which are inclosed within a low brick wall, and a portion of this space is occupied by the only short open spaces above the railway, which were permissible upon this part of the Victoria Embankment. A handsome balustrade surmounts the dwarf wall, and gives a fine effect to the otherwise exceptionally good appearance of the station. We notice that Mr. Frederick Ransome has been intrusted with the construction of this balustrade, for which his artificial stone has been employed, and we believe that it is one of the most, if not the most, successful applications of his process. The plinth, pedestals, piers, and cornices of the balustrade have a uniformity of texture and color, that promise well for their durability, and give them an appearance of wrought stone; indeed, the absence of tool-marks is almost the only indication of their material. The plinths and cornices are cast in convenient lengths, cored, and with slight recesses at the ends, the surfaces of which were roughed up while the material was plastic, in order to give the cement at the joints a better hold; the piers are made in four pieces, the front with deep sharp cut mouldings, the back and the sides with half pillars cast on them. The pillars of the balustrade are made in three pieces, the base and cap being made with pins, which fit into corresponding holes

in the shaft of the pillars. In the curved portion of this balustrade the cornices only were cast in special moulds, the plinths and slabs forming the piers having had slots cut at the back, after which they were laid upon a curved template while in a plastic state, and so brought to the desired form. We believe that some alterations are to be made in the elevation of the Temple Station, and that the parapet that runs along the roof, and behind which is the Norfolk-street approach to the Victoria Embankment, is to be removed, and replaced by a balustrade of the same character and material as the one now being erected on the lower level.

We alluded some time since, and on more than one occasion, to the successful arrest of decay in stone by the application of the preserving material produced by Mr. Ransome, and we find that the process is being largely and profitably employed in Bombay. The Porebunder stone used for building purposes in that city and the locality, is of a very perishable nature, and a number of public buildings in which it had been employed have been showing signs of rapid deterioration. This decay has, however, been arrested by induration, and, as a natural consequence, the demand for the Ransome solution is considerably increasing in Bombay. Attention is also being carefullydirected towards the manufacture of artificial stone. It is now two years since Government works for its manufacture were started, but prejudice has steadily set its face against the material hitherto, so that it has not yet received a fair trial. The lack of endurance, however, in the natural building stone, and the necessity of procuring some more lasting material, has induced the Government to renew their efforts in making stone, and it is now intended to increase the existing works. Both branches of Mr. Ransome's process appear therefore to have a fair chance of extensive adoption in this part of India.

ON THE APPLICATION OF THE CENTRE RAIL SYSTEM TO A RAILWAY IN BRAZIL, AND TO OTHER MOUNTAIN LINES; ALSO ON THE ADVANTAGES OF NARROW GAUGE RAILWAYS.

By MR. J. B. FELL, C.E.

From "The Artizan."

Since the opening of the Mont Cenis Railway in June, 1868, other mountain lines on the centre rail system have been under consideration in different parts of the world. One of these lines now being constructed is in Brazil. It commences at the terminus of the Canta Gallo Railway, crosses the Serra at an elevation of 3,000 ft. above the Canta Gallo Line, and terminates at the town of Novo Friburgo, a distance of 20 miles. In some of its principal features this resembles the summit line of the Mont Cenis, the gradients for the passage of the Serra over a distance of 10 miles, being principally from 1 in 20 to 1 in 12, and the curve by which the line winds round the spurs or counterforts of the mountain being, for a considerable portion of it, from 40 to 100 metres radius. The narrow gauge of 1.10 metres has also been adopted. In other features, however, there is an important difference between these two centre-rail lines. The concession for the Mont Cenis was but temporary, terminating at the completion of the great tunnel, and the railway is laid on the existing public road, whereas the Canta Gallo Line will be permanent, and the works will be so constructed as to be especially adapted to its requirements. It will not have to contend with the difficulties of an Alpine climate, and, profiting by the experience of two years' working on the Mont Cenis, it will have the advantage of important improvements which have been made in the engines, carriages, and permanent way during that period. Consequently, the Canta Gallo and other similar lines, now being or about to be commenced, have the interest of marking a development of the capabilities and advantages of the centre rail system, as applied to the construction and working of mountain railways. It may be useful here to record what has already been accomplished in the task of carrying railways over mountain passes, hitherto inaccessible to the locomotive,

and of giving it the power of safely carrying trains of passengers and goods upon gradients and curves which would previously have been considered most perilous, and, indeed, impracticable. The Mont Cenis Railway has now been open for traffic 2 years and 3 months, and during that period the trains have run a distance of more than 200,000 miles, have carried between France and Italy over 100,000 passengers without injury to any one of them, and has effected the transport of a considerable quantity of merchandise. Since the month of September last, it has carried the accelerated Indian mail, and by the service thus established the delivery of the Indian mail in London *via* Marseilles has been anticipated by the Brindisi and Mont Cenis route by about 30 hours. The ordinary mails between France and Italy have been carried by the Mont Cenis Railway since its opening, and one night of travelling has been cut off the journey between Paris and Turin. Although the Mont Cenis Railway cannot be taken as a type of the best or most approved application of the centre rail system, it has had the effect of proving its mechanical practicability and safety when put to the most crucial test to which any new principle could be submitted. There have been mechanical defects in the construction of the engines which have added unnecessarily to the cost of traction, and these defects can and will be removed in the engines about to be built for the Brazilian and for future centre rail lines. The cost of traction, as might be expected under the circumstances, has hitherto been high—about 3f. per train kilometre; but there can be no doubt that with improved engines and good management the cost of traction may be reduced to 1f. 50c. per train kilometre. The Semmering incline in Austria furnishes an example of the economy that may be effected by improved machinery and management, the cost of locomotive power having been reduced from 2.85 francs in 1860 to 2.15 francs in 1863, 1.70 franc in 1865, and 1.49 franc in 1866. In the four new engines last built for the Mont Cenis Line a considerable saving has been made in the cost of repairs by using four cylinders in place of two. By this arrangement the inside and outside mechanisms are disconnected, and any contention between the two is avoided. The adhesion, however, is equal to the two cylinder engines, and the power is transmitted from the inside cylinders to the vertical axles by means of a train of toothed wheels. In the new engines for the Canta Gallo Line it is proposed to dispense with the toothed wheels and substitute for them a system of direct driving by connecting rods. The power of adhesion will also be considerably increased. These new engines will have the advantage of being able to run at a speed of from 20 to 30 miles an hour upon the ordinary gradients of the line, and of taking their loads up the mountain section at a diminished speed of from 8 to 10 miles an hour. In an economic point of view the result of the application of the centre rail system to the Canta Gallo Railway will be as follows: The cost of construction, assuming it to be as estimated, about £300,000, would be at least doubled if made on gradients upon which ordinary engines could work. In this case the costs of traction and maintenance for a centre rail line will not be greater than for a line with ordinary gradients passing over the same country. The clear saving, therefore, effected by employing the centre rail system is at least £300,000, and the construction of a valuable line of railway has been rendered possible which would otherwise have been commercially and financially impracticable. A somewhat similar line of railway is under consideration by the Indian Government, from the port of Karwar to Hooblee, in the Southern Mahratta country, both by way of the Arbyle and the Kyga Ghats. The distance is 90 miles, and it is proposed to employ the centre rail for a length of about 10 miles upon gradients of 1 in 20 for the passage of the Ghat, by which a saving would be effected of about £500,000. The cost at the present time of the transport of cotton and other produce over the 90 miles is stated to be £235,000 per annum, and there is in addition the disadvantge of not being able to convey the whole crop to the port of shipment before the rainy season sets in; a large portion of it has consequently to be housed and kept until that is over. Negotiations are going on with the Government local authorities and people interested for the construction of centre rail lines in Italy from the Adriatic to Maserata and crossing the Appenines to Foligno from Florence to Faenza, and for

three branch railways in the Neapolitan States; in France, from Chambery to St. André du Gaz and Lyons direct, crossing the Col de l'Epine; in Switzerland, for the passage of the Simplon; and in Spain, for lines from Leon to Corunna and Gion. The concession for the Mont Cenis Railway expires on the opening of the tunnel line, and when that period arrives it has been proposed to remove it to one of the neighboring mountain passes where it would have a permanent life. At the time the concessions were granted it was considered that the line would be worked for ten, or at least seven, years; the progress of the great tunnel has, however, been so much accelerated that it is stated the tunnel line may possibly be opened for traffic by the end of 1871. In that case, and taking into account the difficulties of all kinds with which the enterprise has had to contend, the Mont Cenis Railway can only be regarded as an experimental line, and the pioneer of a system destined to confer the benefits of a cheap and safe communication between many countries separated by mountain ranges hitherto impassable by railways and locomotive engines, and the promoters must look to the future for the reward of their labors and the anxieties of the past. Drawings were exhibited of a new system of narrow gauge or suspension railways, an example of which has recently been constructed as a branch line for carrying iron ore from the Park-house mines to the Furness Railway in North Lancashire. The gauge of this line is eight inches, and the length about one mile. It is carried at various elevations from three to 20 feet over an undulating country, passing over the fences, roads, and watercourses without requiring the construction of earthworks or masonry. The structure consists of a double beam of wood, supported at intervals on a single row of pillars. The narrow gauge is practically made equivalent to a broader one by the steadying power of guide rails fixed on the sides of the beam and below the carrying rails. The bodies of the wagons are suspended from the axles, and by this means the centre of gravity is brought low. They are also furnished with horizontal wheels which run upon the guide bars, and thus maintain the equilibrium of the carriages, and render it almost impossible for them to leave the rails. The Park-house line have a traffic of 50,000 tons per annum. The cost has been £1,000 per mile without stations or rolling stock. It was worked by a stationary engine and endless wire rope. The saving effected in the cost of transport will be at least 6d. per ton upon the distance of one mile. In Switzerland application has been made to the Government of the Canton Vaud for a passenger line on this principle, from the town of Lausanne to the lake of Geneva. Plans have also been laid before the War Office for accelerating military transport in foreign countries, and before the Governor-General of India for the construction of cheap branches from the trunk lines in that country. The gauge of these railways may be from 6 to 18 inches. They may be made of wood or iron, or of the two combined, and may be worked by either stationary engines or by locomotives of a form specially designed for the purpose. They have the advantages of being economical in both construction and working, they occupy but little land, and cause no severance, they may be erected with great rapidity, and being portable may be removed when no longer required and re-erected in another locality. Before the war commenced, an offer was made to the French Government to construct one of these portable railways to supply their army with from 1,000 to 3,000 tons of ammunition and provisions per day. The work would have been undertaken by a gentleman in Paris, who, with a force of 2,500 men, would have constructed from four to five miles of railway per day, following the advance of the army into Germany. The result has, however, shown how little such a provision was needed.

PORT DARWIN AND PORT AUGUSTA TELEGRAPH.—The South Australian Government have now a formidable enterprise on hand, nothing short of the establishment of a telegraph line from Port Darwin to Port Augusta. The cost of establishing this line, which will run quite across the Australian continent, is officially estimated at £130,000.

WELCH'S patent preservative and anti-fouling cements for the bottoms of iron ships, after lengthened and severe trial by the Admiralty, are pronounced successful.

THE HISTORY OF MILITARY FIRE-ARMS.

From "The Mechanics' Magazine."

That gunpowder was used by the Chinese early in the seventh century is among the things not generally known. It was in the form of Greek fire, and was mainly used by the Celestials for the blasting of rocks. In the year 668 it was first employed in warfare, though in what way there is no record to show. Judging from other evidences of scientific progress in China at that early period, it is not improbable that some rude kind of fire-arm was devised and kept secret among the dwellers within the Great Wall, through the centuries that intervened before the use of gunpowder in Europe. We do not read of cannon being used before the year 1327, when Edward III. employed them in his first campaign against the Scots. The French also used cannon in the battle of Cressy, about twenty years later. At that time they were formed of an iron tube, strengthened by large rings of the same material, which being driven on while red hot formed by contraction a gun of great strength and firmness. In the reign of Henry V. bolts and "quarrels" were shot from cannon. These were succeeded by stones, and stones in turn gave way to iron bullets.

In the meantime hand guns had been invented. They were introduced into England by Henry IV., when he landed at Ravenspur, in 1471. The invention of hand guns is ascribed to the Germans, and probably dates half a century prior to their use in this country. A Birmingham gunmaker informs us that at first the hand gun was a simple barrel with an uncovered touch-hole at the top, mounted upon a straight stock, and was fired from a rest by means of a match. A few years afterwards the stock was bent, and the match-lock introduced. The accidents arising from these primitive guns were, as may be supposed, very numerous. The wheel-lock, an Italian invention, which lessened the danger of firing, was introduced in the reign of Henry VIII., and continued to be generally used for a century and a half. Fire-arms, however, were not at that period greatly relied upon for the purposes of war. The awkwardness of the guns, together with the great difficulty and expense of procuring gunpowder, led to a prevailing preference for old appliances, and so late as Elizabeth's time archers were the great strength of the English army.

Sir James Turner states that the pistol was invented at Pistoja, in Tuscany, by Camillo Vitelli in the sixteenth century, and another great authority, M. de la None, remarks :—"The Reiters first brought pistols into general use, which are very dangerous when properly managed." These Reiters, or more properly Ritters, were the German cavalry, who gave such ascendancy to the pistol as to occasion in France, and subsequently in England, the discontinuance of the use of the lance.

Bayonets were first made at Bayonne about the middle of the seventeenth century. Poigniards were the earliest weapons of this class, and were made with wooden handles fitting to the bore of the gun. A socket, by which it was fixed on the muzzle, was added subsequently, and in this improved form bayonets were first used by the French in the reign of William III., to the intense astonishment of our 25th Regiment of Foot.

The flint lock is of Dutch origin, and was invented in the reign of Charles II. It has undergone little essential alteration until within the last thirty years, during which latter period its modifications have been numerous and important.

Oddly enough, the idea of igniting gunpowder by the application of a fulminating substance first occurred to a clergyman—the Rev. Mr. Forsyth—in the year 1807. Although the subsequent experiments of Mr. Forsyth did not succeed according to his expectations, the idea set other minds to work, and a few years later one Joseph Egg invented the percussion cap. This was in 1816 ; but, strange to say, it was not until 1839 that they were used in the military service of England, and they were not adopted by the French until the following year.

It is popularly supposed that the rifled barrel is a modern invention. This is a mistake. Barrels were grooved by the Germans as early as the fifteenth century, and spiral grooves giving the ball a rotary motion were made at Nuremburg in the year 1620. The Poles were probably the

first to use rifles in military service, but it was not until the American war in 1794 that they were placed in the hands of English soldiers.

To enter into all the modifications of the rifle during the last quarter of a century would be to weary the reader with a mass of technical and for the most part uninteresting details. We may, however, allude to one notable improvement. The great difficulty of loading the rifle when the ball encased in a patch of leather had to be driven into the barrel with great force prevented its extended use until within the last twenty years, when the difficulty was surmounted by the substitution of bullets which expand in firing, and which do not require to fit the barrel closely in loading. This is the system adopted in the Enfield rifle now used in the English service. Among the inventors by whose efforts the rifle has been brought to its present degree of perfection may be named M. Deloigne, a French officer, Mr. Greener, of Birmingham, Colonel Thonvenin, Captain Minie, Sir Joseph Whitworth, Mr. Westley Richards, Mr. Snider, and Mr. Terry.

We may now proceed to notice in a few words the three chief small arms of the period—the Snider-Enfield, the Chassepot, and the Prussian needle-gun. These guns are all made upon the same leading principles, which are the breech-loading action and the substitution of a cartridge for the percussion cap. The Prussian needle-gun resembles the Chassepot in one important feature. The breech in either gun is opened by the pulling back of a bolt, which, when the charge is inserted, is pushed home and turned down. In the Snider another plan is adopted; a solid block is lifted out of the breech, the charge is inserted into the barrel in front of it, and the block replaced. The various ways of hinging this block and securing it when down form half of the varieties of breech-loaders. In one the block turns over to the right, in another to the left, in one backwards, in another forwards, all differing in some minor, though perhaps essential, detail, but the leading idea is the same. Two of these three fire-arms are now being practically tested in the greatest tourney the world has seen, with what results our readers are sufficiently familiar.

Birmingham and Liege are the great centres of the gun trade in Europe. In numbers Birmingham is outstripped by her Belgian rival, but in value and quality the "hardware village" carries off the palm. In 1864 the number of guns of all descriptions which passed the Government proof-house at Liege was as follows;—

Single guns	202,216
Double guns	96,616
African muskets	13,682
Saddle pistols	11,653
Pocket pistols	172,962
Military guns	177,754
Total	674,882

The statistics obtainable with regard to Birmingham produce during the same year (which we have selected as being an average year) are in less complete detail, but in the sum total they are 17 per cent. less than those of Liege. In aggregate value, however, the Birmingham guns produced in the same period show a superiority of more than one-fifth over those of its great Continental rival. The Government factory at Enfield, and the Small Arms Company at Small Heath, near Birmingham, now almost exclusively monopolize the military gun trade of Great Britain. At the latter establishment, which is the only one in Birmingham where guns are made on the interchangeable system, the present rate of production is 2,000 per week. The recent extravagant reports of guns produced in Birmingham for the French Government are falsified by the numbers quoted to all readers who are acquainted with the local capabilities of production. As a matter of fact, no guns are being supplied by Birmingham to either of the belligerent powers, unless it be by some artful stratagem of which the manufacturers are wholly ignorant.

The mitrailleuse field-piece is by this time too well-known to need description here. The central idea carried out in this terrible engine of destruction is the binding together of a large number of rifles mounted on a carriage, and by a mechanical appliance discharged simultaneously. This idea has been perfected with slight modifications, both by France and Germany, but the invention is by no means new to England, Mr. Goddard, of Birmingham, having submitted a design for a mitrailleuse gun to the English Government years ago, and before it was

known that the Continental powers had devised or even thought about any such weapon of warfare. With this combination gun we may for the present close these fragmentary notes on military firearms, only remarking that the achievements of modern science and the enterprise of modern industry have despoiled warfare in these days of its olden romantic chivalry, and rendered it little better than a system of wholesale murder by machinery.

IRON ARCHES.

(*Continued from page 455.*)

PROPOSITION VII.

To form the explicit value of M, for every point of the arch.

In the expression for M, arrived at in Proposition III., the value just indicated for H is to be substituted. It (the value for H) multiplies

$$R\,(\cos\theta - \cos\alpha)$$

PROPOSITION VIII.

To find the place where the bending moment is greatest.

Since a and b are supposed constant, M must be maximum at such place or places. Therefore, differentiating the expression for M, arrived at in Proposition III., and omitting the multiplier R, we get

$$0 = -(a\,b\,R + H)\sin\theta + a\,b\,R\,(\sin\theta + \cos\theta) + \frac{W}{2}\cos\theta, \quad \text{or}$$

$$0 = -H\sin\theta + a\,b\,R \times \theta\cos\theta + \frac{W}{2}\cos\theta.$$

This equation can only be solved in a numerical form. The point or points indicated by it correspond to maxima of the bending moment.

There is, however, another most important breaking point, which the investigation by evanescence of the differential coefficient fails to indicate; and the reason is very remarkable. In forming the value of M (Proposition III.), we have taken the mechanical movements of all the forces on the left of P, namely, of abutment reactions, and of weight of the arch on the left of P. If, in this manner, we investigate the bending moments, at successive points from A towards W, always taking forces on the left of P, we have still only abutment reactions and arch on the left of P. But if we continue on the same system of always taking forces on the left of P, as soon as we pass the weight we have the weight W in addition to the abutment reactions and arch on the left of P. Here is a new element introduced. In consequence of this, the function expressing M is discontinuous; $\frac{d\,M}{d\,\theta}$ changes *per saltum* at W, and we have no evidence from $\frac{d\,M}{d\,\theta}$ whether it is there maximum or not. Usually (not invariably) in such cases, M is maximum or minimum; and it is so here, being in maximum negative (as will easily be perceived from the nature of the forces' action), or tending to break the crown downwards with maximum force.

Example:

Let $\alpha = 60°$.

The equation in Proposition VI. for the determination of H will be found to give

$$H = a\,b\,R \times .785 = \frac{W}{2} \times 1.261$$

Substituting this value of H arrived at in Proposition III., we get for the bending moment M at any point, R×the following quantity

$$(a\,b\,R \times 1.785 + \frac{W}{2} \times 1.261)\,(\cos\theta - \tfrac{1}{2}) +$$

$$a\,b\,R\,(\theta.\sin\theta - .907) + \frac{W}{2}\sin\theta - .866),$$

and in like manner the equation which determines the place of maximum bending moment (Proposition VIII.) becomes by substitution

$$0 = (-a\,b\,R \times .785 - \frac{W}{2} \times 1.261)\sin\theta +$$

$$a\,b\,R \times \theta.\cos\theta + \frac{W}{2} \times \cos\theta$$

To proceed further we must assign a numerical value to W, and we shall make three suppositions as follows:

Supposition 1.

Let $W = 0$

The equation for place of greatest moment becomes

$$-.785 \sin\theta + \theta\cos\theta = 0 \text{ or } \tan\theta = \frac{\theta}{.785}$$

The solutions of this are sensibly $\theta = 0°$ $\theta = 45°$
Hence the two breaking places are at $\theta = 0°$ $\theta = 45°$

The expression for bending moment becomes

$$M = a\,b\,R^2 \times \{1.785\,(\cos\theta - \tfrac{1}{2}) + (\theta.\sin\theta - .907)\}$$

when $\theta = 0$ this becomes $M = -\,a\,b\,R^2 \times .014$
when $\theta = 45°$ it becomes $M = +\,a\,b\,R^2 \times .018$

(The negative sign in the first value of M denotes that the joint opens below).

Hence the weakest place is at 45°.

Supposition 2.

Let $W = R.\ a.\ b.$

(This is nearly, but not quite, the same as supposing that the load on the crown= weight of one-half of the arch).

One solution for the place of greatest bending moment is θ=0, the other is given by the equation

$$-1.416.\ \sin\theta + (\theta + \tfrac{1}{2})\cos\theta = 0 \text{ or } \tan\theta = \frac{\theta + 0.5}{1.416}$$

the solution of which is $\theta = 41°$ nearly.

The expression for bending moment becomes

$$M = ab\,R^2 \times \{2.416 \times \cos\theta + \theta.\sin\theta + \tfrac{1}{2}\sin\theta - 2.548\}$$

when $\theta = 0$ this becomes $M = -\,a\,b\,R^2 \times .142$
when $\theta = 41°$ it becomes $M = +\,a\,b\,R^2 \times .072$

Hence the weakest place is the crown of the arch. The bending moment at the crown is ten times as great as in supposition 1; that at the haunch is four times as great.

Supposition 3.

Let $W = 2\,R\,a\,b.$

(This is nearly the same as supposing that the load on the crown=weight of the whole arch.)

One solution for the place of greatest bending moment is θ=0. The other is given by the equation

$$-2.046.\ \sin\theta + (\theta + 1)\cos\theta = 0 \text{ or } \tan\theta = \frac{\theta + 1}{2.046}$$

The solution of this equation is $\theta = 39°$ nearly.

The expression for bending moment becomes

$$M = a\,b\,R^2 \times \{3.046 \times \cos\theta + \theta.\sin\theta + \sin\theta - 3.296\}$$

when $\theta = 0$ this becomes $M = -\,a\,b\,R^2 \times .250$
when $\theta = 39°$ it becomes $M = +\,a\,b\,R^2 \times .128$

Hence the weakest part is the crown.

The bending moment is eighteen times greater than in supposition (1).

PROPOSITION IX.

To investigate the bending moment at any point of the arch when the weight is eccentric.

Let β be the angle which defines the position of the weight, as in the diagram; then the vertical forces K, K', at the abutments will become respectively

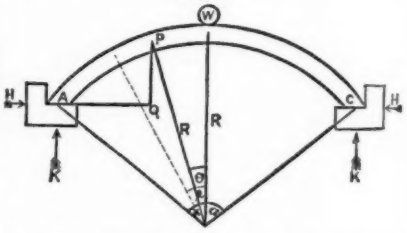
$$R.\ \alpha.\ a.\ b + W \times \frac{\sin\alpha + \sin\beta}{2\sin\alpha},$$

and

$$R.\ \alpha.\ a.\ b + W \times \frac{\sin\alpha - \sin\beta}{2\sin\alpha}.$$

The general principles of the investigation will be those of Propositions III. to V., but a peculiar caution is necessary, because the moments produced by the weight W have to be taken differently for points on its two sides. This apparent complexity might be avoided by measuring the moments in opposite directions on the two sides of W. The process will, however, be rendered more intelligible by always proceeding with the arc from the right abutment towards the left, and always taking the moments of parts towards the left.

FIG. 4.



Section (1). For a point between the right abutment and the weight: that is, for values of θ included between $-\alpha$ and $+\beta$.

The forces on the left hand of the point, producing moments about the point, are

The weight of the portion from the point to A.
The force H.
The weight W acting immediately.
The force $K = R\,\alpha\,a\,b + W \times \frac{\sin\alpha + \sin\beta}{2\sin\alpha}$.

The first three of these forces tend to bend A downwards and inwards, and the last to bend A upwards and outwards. They produce (nearly as in Proposition III.) the bending moment.

$$M_1 = \left\{\begin{array}{l} a.b.R^2(\cos\theta + \theta\sin\theta - \cos\alpha - \alpha.\sin\alpha) \\ +H.\ R.\ (\cos\theta - \cos\alpha) \\ +W\,R\,(\sin\beta - \sin\theta) \\ +W \times \dfrac{\sin\alpha + \sin\beta}{2\sin\alpha} \times R\,(\sin\theta - \sin\alpha) \end{array}\right\}$$

And, as in Propositions IV. and V., this moment, in the space $\delta\theta$, produces a curvature expressed by multiplying it by E

R. $\delta\,\theta$; and produces a spread of A expressed by multiplying it by

$$\mathrm{R}\,(\cos\theta - \cos\alpha).$$

Hence, for the spread produced by the whole part between the right abutment and W, we have to integrate $\mathrm{E.\,R.^2\,M_1}\,(\cos\theta - \cos\alpha)\;\delta\;\theta$ from $\theta = -\alpha$ to $\theta = +\beta$.

Section (2). For a point between the weight and the left abutment; that is, for values of θ included between $+\beta$ and $+\alpha$.

On this section there is no force W to the left of the point: the bending moment is,

$$\mathrm{M_2} = \left\{\begin{array}{l} a\,b\,\mathrm{R_2}\,(\cos\theta + \theta.\sin\theta - \cos\alpha - \alpha.\sin\alpha) \\ +\mathrm{H.\,R}\,(\cos\theta - \cos\alpha) \\ +\mathrm{W.}\dfrac{\sin\alpha + \beta}{2\sin\alpha} \times \mathrm{R}\,(\sin\theta - \sin\alpha) \end{array}\right\}$$

and $\mathrm{M_2}$, as before, is to be multiplied by ER. $\delta\,\theta$, and by R $(\cos\theta - \cos\alpha)$, to find the spread which the bend in the small piece $\delta\,\theta$ produces. Hence for the spread produced by the whole section between the weight and the left abutment, we have to integrate $\mathrm{M_2.\,E.\,R_2}\,(\cos\theta - \cos\alpha)\;\delta\;\theta$ from $\theta = \beta$ to $\theta = \alpha$.

Then, as in Proposition VI., the total spread (the sum of the two integrals) is to be made $= 0$; H will be determined from this equation, and its value must be substituted in the expressions for $\mathrm{M_1}$ and $\mathrm{M_2}$. The bending moment at any point of either section of the arch will then be obtained; it will have one maximum value where $\theta = \beta$, and one other maximum value in each section of the arch where $\dfrac{d\,\mathrm{M}}{d\,\theta} = 0$.

The total spread of the foot A of the arch is thus obtained. The three integrals in Section (2) are similar to the 1st, 2d, and 4th integrals in Section (1); the latter are to be taken between limits $-\alpha$ and $+\beta$, and the former between limits $+\beta$ and $+\alpha$. The sum of the two parts of each integral, therefore, constitute integrals to be taken between limits $-\alpha$ and $+\alpha$. The result of the integration will give (omitting the general factor $\mathrm{E.\,R^3}$),

$$\begin{array}{l} (a\,b\,\mathrm{R} + \mathrm{H}) \times \left\{-3\sin\alpha\cos\alpha + \right. \\ \qquad \left. \alpha\,(\sin^2\alpha + 3\cos^2\alpha)\right\} \\ + a\,b\,\mathrm{R} \times \left\{-\frac{8}{3}\sin\alpha\cos\alpha + \right. \\ \left. \alpha\,(\frac{8}{3}\cos^2\alpha - \frac{8}{3}\sin^2\alpha) + \alpha^2\,2\sin\alpha\cos\alpha\right\} \\ + \mathrm{W}\dfrac{\sin\alpha + \sin\beta}{2\sin\alpha} \times (-2\sin^2\alpha + 2\sin\alpha\cos\alpha). \end{array}$$

The 3d integral in Section (1) is to be taken only between the limits $-\alpha$ and $+\beta$. It will be found to give a result,

$$\mathrm{W} \times \left\{\tfrac{1}{2} + \tfrac{1}{2}\sin^2\beta + \tfrac{1}{2}\cos^2\alpha - \cos\alpha.\cos\beta + \sin\alpha.\sin\beta - (\alpha + \beta)\cos\alpha.\sin\beta\right\}.$$

And collecting all the terms, we obtain for the entire inwards spread,

$$\mathrm{E\,R^3}\left\{\begin{array}{l} \mathrm{H} \times \left\{-3\sin\alpha.\cos\alpha + \alpha\,(\sin^2\alpha + 3\cos^2\alpha\right\} \\ +ab\,\mathrm{R} \times \left\{-\frac{8}{3}\sin\alpha.\cos\alpha + \alpha(-\frac{1}{3}\sin^2\alpha + \frac{8}{3}\cos^2\alpha) + \alpha.\,2\sin\alpha\cos\alpha\right\} \\ +\mathrm{W} \times \left\{\frac{2}{3}\cos^2\alpha - \frac{1}{3}\cos^2\beta - \cos\alpha.\cos\beta + (\alpha.\sin\alpha - \beta.\sin\beta).\cos\alpha\right\} \end{array}\right.$$

(The following partial verifications are to be found on comparing this formula with that obtained in Proposition V.: (1) When $\beta = 0$, its value is double that of the spread in Proposition V.; (2) The powers of (β) are even, as will be seen by expanding the functions of β; (3) When $\beta = \alpha$, the coefficient of W vanishes.)

Example:

Let $\alpha = 60°$ $\beta = 30°$

Then substituting these values of (α) and (β) in the last equation, we obtain

$$\text{Spread of A} = \mathrm{E.\,R^3} \times \left\{\mathrm{H} \times .2718 - a\,b\,\mathrm{R} \times .2134 - \mathrm{W} \times .1104\right\}$$

and putting this $= 0$, we obtain

$$\mathrm{H} = a\,b\,\mathrm{R} \times .785 + .406$$

The absolute bending moment $\mathrm{M_1}$, for any point between $\theta = -\alpha$ and $\theta = +\beta$, is found by substituting this value of H in the expression for $\mathrm{M_1}$, and we shall find

$$\mathrm{M_1} = \left\{\begin{array}{l} a\,b\,\mathrm{R} \times \left\{1.785\cos\theta + \theta\sin\theta - 1.800\right\} \\ \quad +\mathrm{W}\left\{.406\cos\theta - .211\sin\theta - 0.386\right\} \end{array}\right\}$$

The absolute bending moment, $\mathrm{M_2}$, for any point between $\theta = +\beta$ and $\theta = +\alpha$ will in the same way be found to be as follows:

$$\mathrm{M_2} = \left\{\begin{array}{l} a\,b\,\mathrm{R}\,(1.785\cos\theta + \theta.\sin\theta - 1.800) \\ \quad +\mathrm{W}\,(.406\cos\theta + .789\sin\theta - 0.886) \end{array}\right\}$$

The two formulæ agree when $\theta = 30°$ or under the weight W. We shall give no further attention to the second, as that side of the arch is the stronger.

To find where $\mathrm{M_1}$ is a maximum, we must make $\dfrac{d\,\mathrm{M_1}}{d\,\theta} = 0$. This will give us

$$\begin{array}{l} a\,b\,\mathrm{R} \times \left\{-1.785\sin\theta + \sin\theta + \theta.\cos\theta\right\} + \\ \quad \mathrm{W}\left\{-.406\sin\theta - .211\cos\theta\right\} = 0 \end{array}$$

from whence we obtain

$$\tan\theta = \frac{a\,b\,\mathrm{R} \times \theta - \mathrm{W} \times .211}{a\,b\,\mathrm{R} \times .785 + \mathrm{W} \times .406}.$$

Let $\mathrm{W} = \mathrm{R}\,a\,b$. Then $\tan\theta = \dfrac{\theta - 211}{1.191}$.

This gives $\theta = -34°$ nearly. Substituting in the expression for M_1 above, we get

when $\theta = +30°$ $\quad M_1 = -.133 \times a\,b\,R^2$
when $\theta = -34°$ $\quad M_1 = +.080 \times a\,b\,R^2$

Therefore the bending moment is greatest for the point under the weight.

Let $W = 2\,R\,a\,b$. Then $\tan\theta = \dfrac{\theta - .492}{1.597}$.

This gives $\theta = -31°$, and, as before, we get,

when $\theta = +30°$ $\quad M_1 = -.274 \times a\,b\,R^2$
when $\theta = -31°$ $\quad M_1 = -.148 \times a\,b\,R^2$

Thus in this case the bending moment is nearly twice as great for the point under the weight as for any other weight.

PROPOSITION X.

To investigate the bending moment at any point of the arch, when the piers present no lateral resistance.

In this case we have merely to make $H = 0$ in the expressions for M, and to enter into none of the calculations for spread. And in the numerical calculation it is only necessary to consider the point under the weight ; and it is certain that, if W be not very small, the arch will break there.

If the weight be central, the value of M (Prop. III.) is R $\times$ the following expression :

$$a\,b\,R \times \{(\cos\theta - \cos\alpha) + (\theta\sin\theta - \alpha\sin\alpha)\} + \frac{W}{2}(\sin\theta - \sin\alpha)$$

when $\theta = 0$, this becomes

$$M = a\,b\,R^2 \times (1 - \cos\alpha - \alpha\sin\alpha) - R\,\frac{W}{2}\sin\alpha$$

and if $\alpha = 60°$, this becomes

$$M = -R\,(a\,b\,R \times .407 + W.433)$$

Let $W = 0$ then $M = -a\,b\,R^2 \times .407$
Let $W = R\,a\,b$ then $M = -a\,b\,R^2 \times .840$
Let $W = R^2\,a\,b$ then $M = -a\,b\,R^2 \times 1.273$

If the weight be eccentric, the value of M_1 (Prop. IX.) is R $\times$ the following expression :

$$\left\{\begin{array}{l} a\,b\,R \times (\cos\theta + \theta\sin\theta - \cos\alpha - \alpha\sin\alpha) \\ + W(\sin\beta - \sin\theta) + W.\dfrac{\sin\alpha + \sin\beta}{2\sin\alpha} \times \\ (\sin\theta - \sin\alpha) \end{array}\right\}$$

and when $\theta = \beta$, this becomes

$$M = a\,b\,R^2 \times (\cos\beta + \beta.\sin\beta - \cos\alpha - \alpha\sin\alpha) - W.R.\frac{\sin^2\alpha - \sin^2\beta}{2\sin\alpha}.$$

And if $\alpha = 60°$ and $\beta\,30°$, this becomes

$$M = -R\,\{a\,b\,R \times .279 + W \times .289\}.$$

Let $W = R\,a\,b$ then $M = -a\,b\,R^2 \times .568$
Let $W = 2\,R\,a\,b$ then $M = -a\,b\,R^2 \times .857$.

Table of results collected from Propositions VIII., IX., and X.

In the following formulæ the section of the arched rib is supposed to be a parallelogram of depth (b) and width (a), R is the radius of the arch at the middle of its depth. The whole arch is supposed to be 120 deg. of a circle, or 60 deg. on each side of the crown. When the weight W is eccentric, it is supposed to be 30 deg. from the crown, or midway between the crown and the springing. M is the bending moment at the point specified.

PART I.

The arch tight within the abutments, so that they receive the full horizontal thrust.

(1)	No weight W	
	At the crown	$M = -a\,b\,R^2 \times .014$
	At 45° from the crown	$M = +a\,b\,R^2 \times .018$
(2)	The weight central	$W = R\,a\,b$
	At the crown	$M = -a\,b\,R^2 \times .142$
	At 41° from the crown	$M = +a\,b\,R^2 \times .072$
(3)	The weight central	$W = 2\,R\,a\,b$
	At the crown	$M = -a\,b\,R^2 \times .250$
	At 39° from the crown	$M = +a\,b\,R^2 \times .128$
(4)	The weight eccentric	$W = +R\,a\,b$
	Under the weight	$M = -a\,b\,R^2 \times .133$
	At 34° from the crown on the opposite side	$M = +a\,b\,R^2 \times .080$
(5)	The weight eccentric	$W = 2\,R\,a\,b$
	Under the weight	$M = -a\,b\,R^2 \times .274$
	At 31° from the crown on the opposite side	$M = +a\,b\,R^2 \times .148$

PART II.

The arch not confined horizontally between the abutments.

(1)	No weight W	
	At the crown	$M = -a\,b\,R^2 \times .407$
(2)	The weight central	$W = R\,a\,b$
	At the crown	$M = -a\,b\,R^2 \times .840$
(3)	The weight central	$W = 2\,R\,a\,b$
	At the crown	$M = -a\,b\,R^2 \times 1.273$
(4)	The weight eccentric	$W = R\,a\,b$
	Under the weight	$M = -a\,b\,R^2 \times .568$
(5)	The weight eccentric	$W = 2\,R\,a\,b$
	Under the weight	$M = -a\,b\,R^2 \times .857$

It will now be proper to apply the formulæ of the foregoing investigation to the circumstances of a practical example in order to show the importance of the bending moment when combined with the thrust force of the arch. The problem will be simplified as much as possible, and may be stated as follows :

Required the sectional dimensions for a continuous wrought-iron arch of 200 ft.

span (measured from centre to centre of the feet of the arch), and 30 ft. mean central rise: the section of the arch to have the form of a single rectangular cell of uniform thickness: the fixed load (comprising the weight of the arch itself and its proportion of the roadway) to be taken at 2 tons per foot run, and the running load at $1\frac{1}{2}$ tons per foot run?

With the above dimensions it will be found that the radius R = 181.666 ft., the half angle of the arch, α = 33 deg. 24 min. (circular measure of α = .5829), and length of arch = 211.8 ft.

We shall treat the case as if the arch were loaded uniformly all over its length; this supposition, though incorrect, will give us a close approximation to the circumstances of the actual case. It is usual to make the strengths sufficient to carry 3 times the fixed load + 6 times the running load. Hence in the case of the example the load per foot run will be $6 + 7\frac{1}{2} = 13\frac{1}{2}$ tons per foot run, or 2,700 tons in the aggregate: this load distributed over the arch will give a uniformly distributed load of $\frac{2700}{211.8} = 12.75$ tons per ft. of the arch.

We shall proceed to determine the strains from consideration of an arch having the same shape and size of the example, and of such sectional dimensions as to weigh 12.75 tons per ft. of its length. Taking 480 lbs. as the weight of 1 cubic foot of wrought-iron, the sectional area must be $59\frac{1}{2}$ sq. ft. It will be understood that the value of the sectional area is merely introduced in this form to suit the unit of weight (1 cubic ft. of iron) adopted in the preceding investigations, and as representing in such units the actual load of 12.75 tons per ft. run.

(1). To find the value of H, which will be the value of the thrust force at the crown of the arch.

Taking the formula for H, given in Proposition VI., and putting W = 0, as there is no weight, W, in the present example,

$$H \times \left\{\tfrac{1}{2}\sin\alpha\cos\alpha - \alpha(\tfrac{1}{2}\sin^2\alpha + \tfrac{1}{2}\cos^2\alpha)\right\} = a\,b\,R \times \left\{-\tfrac{1}{2}\sin\alpha.\cos\alpha + \alpha(\tfrac{1}{2}\cos^2\alpha - \tfrac{1}{2}\sin^2\alpha) + \alpha.^2\sin\alpha.\cos\alpha\right\}$$

and putting $\alpha = 33° 24'$, the above equation will be found to give a result,

$$H + .0085 = a\,b\,R \times .0079 \text{ or } H = .93 \times a\,b\,R$$

(2). To find the place of maximum strain. The equation is found in Proposition VIII.

$$0 = -H.\sin\theta + a\,b\,R \times \theta\cos\theta.$$

or,

$$0 = -.93 \times \sin\theta + \theta\cos\theta.$$

This gives $\tan\theta = \frac{1}{.93}$, and the solution is found by trial to be $\theta = 26°$; $\theta = 0$ will also define a point of maximum strain.

(3). To find the bending moment, and the thrust force, at the points defined by $\theta = 0$, $\theta = 26°$.

The equation for the bending moment is found in Proposition III.; it becomes, putting W = 0, and substituting the value of H,

$$M = a\,b\,R^2 \times 1.93 \times (\cos\theta - \cos\alpha) + a\,b\,R^2 \times (\theta\sin\theta - \alpha\sin\alpha),$$

when $\theta = 0$ and $\alpha = 33° 24'$. $M = -.0023 \times a\,b\,R^2$.
when $\theta = 26°$ and $\alpha = 33° 24'$. $M = +.0054 \times a\,b\,R^2$.

Thus the bending moment is greatest at the point $\theta = 26°$, and its numerical value at that point is

$$M = .0054 \times a\,b\,R^2 = .0051 \times 59\tfrac{1}{2} \times (181.66)^2 = 10603.$$

The thrust force at the crown is H = .93 $\times$ a b R, and the thrust force at the point $\theta = 26°$, will be H $\times$ sec 26°.

$$= .93 \times a\,b\,R \times 1.112 = 11177.$$

(The units being the ft., and the weight of a cubic ft. of wrought-iron.)

(4) To determine the dimensions of the section so as to bear the strain due to the thrust force and the bending moment without exceeding a maximum thrust of 12 tons per sq. in. at the compressed surface of the arch.

The best way to do this will be by trial, thus: We shall assume the depth and width of the section, and determine the thickness of the shell, so that the sectional area shall be greater than would be necessary to endure the thrust force only. Thus we shall assume the thickness in our example, so as to give a sectional area of $\frac{2391}{7}$ square in. (the thrust force = 11,177 cubic ft. = 2,391 tons) instead of $\frac{2391}{12}$ sq. in., which would be about the least that would resist the thrust force only. We shall then try if this section will endure the bending moment in addition without producing a greater additional strain at the parts furthest from the neutral line (on the compressed side of the arch) than 5 tons per sq. in.,

which, together with the 7 tons already assumed to be caused by the thrust force only, will bring the metal at the outside of the section to its limiting endurance of 12 tons per sq. in. This will be the first trial, and if the section will not resist the bending moment in addition to the thrust force, we must make a second trial with altered assumptions.

Let, then, the depth of the rib be 6 ft., and the breadth 4 ft., and let the uniform thickness be k; then the sectional area will be $20 \times 12 \times k = 240.k$ sq. in. nearly. Now the thrust force = 2,391 tons, and the sectional area required to resist this force, allowing 7 tons per sq. in. is $\frac{2391}{7}$ = 342 sq. in., nearly. Therefore, $240 \times k = 342$, and $k = 1.425$ in. = .11875 ft.

Now, the moment of the forces resisting the bending moment, in the case of a cell section such as that assumed, is:

$$\frac{2}{3}\frac{t}{f}\left[a\left\{f^3-(f-k)^3\right\}+2k(f-k)^3\right]$$

Where t = strain of the metal at the outside of the arch on the compressed side, and f = distance of the neutral axis from the same side of the arch. In the present case, the section being symmetrical, we have f = half depth of rib = 3 ft.; also $a = 4$ ft., and $k = .11875$ ft. The above expression becomes $= 4.t$ very nearly. If we put this equal to the bending moment, we obtain $4.t = 10603$, and

t = 2651 cubic feet of iron per sq. ft. of section.
= 568 tons " " " "
= 3.94 " " sq. in. "

Thus the total strain on the metal at the outside surface of the arch (where it is most strained) is $7 + 3.94 = 10.94$ tons per sq. in., which does not exceed the limiting strength of 12 tons. The arch is therefore safe, and the thickness of the shell might with safety be somewhat reduced.

It is worth while to notice by this example how exceedingly fallacious a result would be obtained, if the bending moment of the forces were neglected. If the arch had formed a larger segment of a circle, as, for instance, if it had been an arch of 120 deg. instead of 67 deg., the bending moment would have been far more serious, and, in such cases, a fairly approximate result would be obtained from consideration of the bending moment only of the forces, without taking any notice of the thrust force as affecting the strain on the material of the arch.

In the early part of this investigation it has been stated that, as regards the equilibrium of the portion of the arch between the point considered and the abutment, the bending moment and the thrust force may be conjointly represented by a single force acting at a point removed from the centre of the section. This resultant force has very little significance in the case of a continuous arch, for both the bending moment and the thrust force are met by similar forces supplied by the material of the arch; but in the case of the voussoir arch, which is unable to meet a bending moment except it be combined with a thrust force, it is indispensable to consider them together as represented by their resultant. This resultant will act at a point removed from the centre of the section by a distance $x = \frac{M}{S}$, where M = the bending moment, and S = the thrust force at the joint considered. By means of this formula the line of thrust may be laid down for a voussoir arch, with a degree of approximation depending on the depth of the voussoirs as compared with the span of the arch. The question as to how near to the surface of the arch the resultant may safely be permitted to approach, so that the arch may not fail by the crushing of the materials, must be decided empirically, as it depends much upon the elasticity of the stone. It is sometimes ruled that the resultant must for safety be kept within the limits of the middle third part of the depth.

It is not intended to pursue the theory of the arch beyond its most ordinary practical application as contained in the foregoing columns. There is no difficulty in applying the same method to elliptic and catenarian arches; but these are of rare occurrence as compared with the circular arches, and the investigation would be more laborious. In case, however, the investigation of such arches should at any time be necessary, it would be found advisable to use rectangular co-ordinates in working out the problem, instead of the polar co-ordinates adopted in the present paper. It has long appeared to the writer that a practical theory of the iron arch was much needed, for with such arches it is an object of great impor-

tance to avoid a superfluity of material. This is not the case with stone arches, which for the sake alike of solidity, cheapness, and convenience, are close-jointed over their whole surface, and, as a contingent advantage, they usually possess a great superfluity of strength when the span is moderate. Moreover, the stone arches have an additional source of strength in the close union which can be effected with the backing and the spandrel walls, and this is very valuable; indeed an instance came before the writer where an entire horizontal row of voussoirs had fallen out of an arch over a stream in consequence of the undermining of the foundations, and yet the arch carried the traffic of a turnpike road without exhibiting any sign of weakness. This source of strength cannot easily be secured for an iron arch, but nevertheless such is the strength of the material and so great are the advantages of continuity that for large spans the continuous iron arch is without doubt the safest, lightest, and strongest form of arch that could be employed.

DUST FUEL.

From "Engineering."

Every year there are produced at our collieries thousands of tons of dust coal, and, although of this vast quantity some small proportion is effectively utilized either by conversion into coke or by being used in the manufacture of the so-called "artificial" fuel, yet by far the greater proportion is either thrown on the waste heap or sold at a mere nominal price. Now, we have here an enormous national loss. Coal dust is certainly, in many cases, contaminated by admixture with foreign matters, but these, if deleterious, can readily be removed by washing, and the dust coal remaining then possesses theoretically the same calorific value, weight for weight, as the lump coal from the same seam. Practically, however, this dust coal is at present regarded as little better than a waste product, and hence there goes on annually a loss which we may justly call "national;" for although it may, in the first instance, fall more directly upon the colliery owners, yet it undoubtedly becomes ultimately a loss to the nation at large, as does everything which diminishes the value of the mineral resources of the country. This being the case, one of the most important questions of the day is, how can this loss be best prevented?

The great thing to be done evidently is to give this coal dust a good marketable value, either by the general employment of processes which will convert it into fuel of a kind meeting with a ready purchase, or by providing means for its economical combustion either in the state in which it is raised from the mines, or after it has undergone a certain cleansing process. In the former direction something has already been done—and much more, no doubt, will yet be done—by the employment of coal-washing machines, and by the conversion of the washed products into coke or artificial fuel; but in the second direction, namely that of providing means for burning the coal economically in a state of dust, little of any real practical value has been done until within the last year or so. No doubt we have had plenty of arrangements of fire-grates, etc., for burning slack coal, but the coal of which we are now speaking is much smaller than that ordinarily known as "slack"—real *dust*, in fact, a material by no means easy to deal with, as those who have experimented on its use well know. No doubt, also, many methods of burning this dust coal have been proposed and tried, with varying degrees of success. The idea of using fuel in a powdered state is very far from being a novel one, and as long ago as 1831 a patent was taken out for one mode of burning such fuel, while between the date just mentioned and the year 1868, considerably over a dozen patents were procured for different modes of attaining the same end. But, as far as we are aware, none of these plans ever achieved such an amount of success as to warrant its extensive application, and we think that we may fairly say that the first really practical coal-dust furnace which has been produced is that constructed on the plans of Mr. Thomas Russell Crampton, which, for many months past, has been doing good service at Woolwich Arsenal.

It is now more than a year since we first

directed the attention of our readers to Mr. Crampton's plans; and since that time we have had many opportunities of examining carefully the various modifications and improvements which experience has enabled Mr. Crampton to introduce for the purpose of either simplifying his furnace or increasing its efficiency. This being the case, we are able to testify, from our own personal knowledge, to the vast amount of ingenuity, energy, and perseverance which Mr. Crampton has brought to bear upon the subject with which he had to deal. Now that a practical success has been attained, there can be no harm in recording that this success was preceded by no small number of failures of a more or less disheartening kind. The great difficulty to be overcome was to obtain a *continuously* good result. To scheme an arrangement by which coal dust could be burnt successfully for a few hours at a time, was a comparatively easy task; but to produce a furnace which could be kept going day and night for a week or more together, and in which, moreover, the heat was at all times under perfect control, was another and very different matter, notwithstanding that now that it *is* done, the whole affair may appear very simple. In the first place, there had to be devised means for supplying the coal dust to the furnace with regularity and at any desired rate; next, provision had to be made for mixing this coal dust thoroughly and equally with the air for supporting combustion; and, finally, there had to be schemed an arrangement of combustion chamber not likely to be damaged by the intense heat, and capable of being readily and cheaply kept in repair.

In the furnace now working at Woolwich, these various ends—none of them of easy attainment—have been fulfilled in a manner which we think we may say is practically perfect. The powdered fuel is fed from a hopper by a pair of smooth-feeding rollers, and the arrangement is such that these rollers always have a certain quantity of loose material to draw from, so that their supply is unaffected by any temporary sticking of the coal dust in the hopper, that may arise from the presence of moisture or other causes. The powdered fuel falling from the feed-rolls is distributed to a series of pipes, through which it is injected into the furnace by means of jets of air supplied by a fan. The idea of injecting coal dust by means of air jets is an old one, and Mr. Crampton lays no claim to be its originator. Early in his experiments, however, he discovered that different modes of introducing into the furnace the jets of mixed air and coal dust produced widely different results, and no small proportion of his researches was devoted to disovering the best mode in which this introduction could be effected. In the furnace now in use at Woolwich, the jets enter the combustion chamber horizontally, opposite the bridge, and by a simple—almost ridiculously simple—arrangement it is insured that the mixture of air and coal dust shall be perfectly equable throughout the entire width of the chamber. The combustion chamber itself is simply formed by placing a fire-brick bottom where the fire-grate is ordinarily situated, provision being made for tapping at intervals the slag which accumulates from the melting of the foreign matters mingled with the coal dust. The main body of the furnace in which the blooms to be heated are placed is of precisely the same form as usual, and the products of combustion, also, pass off to a chimney in the usual way. By means of a damper in this chimney the draught can be readily adjusted, so that, owing to the action of the air-jets, there is at all times a slight plenum within the furnace, and thus, even if the door be opened, the interior is not cooled by the rush of cold air. This is an important point, as all who have had the management of furnaces will understand.

Such is a general outline of the plans on which the furnace at Woolwich is constructed, and we must now speak of the results obtained. In the first place we may state as evidence of the perfection of the fuel-feeding arrangements that the furnace has turned out fifty successive heats, averaging 30 cwt. of blooms per heat, *without the handles governing the supplies of air and coal ever having been moved.* Next, numbers of heats have been turned out with a consumption of less than 5 cwt. of coal per ton of blooms, and the weekly averages during regular work have shown a consumption of but about 6 cwt. per ton of iron turned out, this being done it must be remembered with dust coal obtained by grinding common slack, costing several shillings per ton

less than the coal ordinarly used at the Woolwich furnaces. Besides being employed on regular work, various experiments have been made with Mr. Crampton's furnace for the purpose of showing the intense heat obtainable by the arrangement. Thus on one occasion there was placed in the furnace, in a pot, 25 lbs. of puddle bar made from $\frac{3}{5}$ coal blast and $\frac{2}{5}$ Staffordshire pig, and this puddle bar which contained 0.04 per cent ot carbon was *melted* in one hour and 45 min., and was then run into a mould and cooled. The ingot was then reheated to a red heat and hammered out into a bar 2 in. sq. ; and this bar on being tested showed a tensile strength of 22 tons per sq. in., this strength being the same as that of bars worked up in the ordinary manner from puddle bars made from the same materials. The 2 in. bar was then heated to a good welding heat, and drawn down into a bar measuring $2\frac{1}{2}$ in. by $\frac{5}{8}$ in., when it was again tested, the result showing a breaking strain of 32 tons per sq. in., and the piece tested stretching $\frac{3}{8}$ in. in a length of $1\frac{1}{2}$ in. before being ruptured. The $2\frac{1}{2}$ in. by $\frac{5}{8}$ in. bar was bent double when cold, without fracture, the edges being quite sharp, and, finally, the iron was analyzed and found to still contain its 0.04 per cent. of carbon.

In another experiment a quantity of turnings from the same quality of puddle bar, which had been worked through the furnace three or four times, was melted in 50 minutes and run over an iron plate, the molten iron making a "cake" having an area of about one square foot, and a thickness varying from about $\frac{1}{64}$ in. to $\frac{1}{4}$ in. This plate or casting—which is perfectly malleable—was exhibited by Mr. Crampton during the recent meeting of the Institution of Mechanical Engineers at Nottingham, and at the same time the various samples obtained during the other experiments were also shown, and attracted, as they deserved, much attention.

A third experiment consisted in melting in a pot 25 lbs. of blister steel, this melting being accomplished in 60 minutes; at least that is the time that the pot was allowed to remain in the furnace, but it is believed that the complete melting of the material was effected in a shorter period. Finally, a small pot of plate glass mixture, which was piled up into a cone and left uncovered, was placed in a comparatively cool part of the furnace, where, however, it was exposed to the direct action of the flame, the result being that the materials were melted down in 20 minutes. The color of the glass was perfect, a good evidence of the completeness of the combustion.

The results we have recorded above are, we think, entitled to the careful attention not only of those directly interested in the utilization of small coal, but also of all who are engaged in metallurgical pursuits, or in manufactures employing high temperatures. The melting of wrought iron in a furnace supplied with cold fuel and cold air is, we believe, absolutely unprecedented, and the fact that such a thing can be accomplished in Mr. Crampton's furnace is in itself a proof not only of the perfection of the combustion, but of the regularity with which the heat is maintained. The temperature required for the melting of the wrought iron is but little below that at which the destruction of the furnace lining would take place, and had there been any material variations of temperature above or below the desired point, there would on the one hand have been a destruction of the furnace lining, and on the other a delay in effecting the melting of the iron itself.

The success which has been attained by Mr. Crampton in the use of powdered fuel opens up a very wide field of research, and it is as yet impossible to say to what improved metallurgical or manufacturing processes it may give rise. Indeed, quite apart from its affording a means of utilizing what has hitherto been almost a waste product, the system possesses great importance, and it is our intention, in a future article, to point out some of the ends to which it may lead, and also to describe more fully the details of the arrangement which Mr. Crampton's laborious researches have led him to adopt.

Intercolonial Railway.—The tender of Messrs. Ellis & Co., for the 20th section of this line, has been accepted by the commissioners for carrying out the undertaking. It is rumored that Bessemer steel rails are to be laid down for the permanent way of the line. Section No. 10 is to be relet. According to present arrangements, the whole line is to be finished by July 1, 1872.

THE USES OF THE BESSEMER METAL.

From "The Engineering and Mining Journal."

In this country but little use has been made of the Bessemer metal, save for the manufacture of rails, while in Europe it has been successfully applied to many other purposes, among which we may mention boiler making, and the construction of many running parts of machinery. It has generally replaced wrought iron, and not steel. The use of the misnomer steel has doubtless been the reason that this metal has not been applied to many purposes for which it appears to be better adapted than either cast-iron, wrought-iron, or steel. Cast-iron and crucible steel, though they are harder than wrought-iron, possess less tenacity; hence, for constructions intended to resist jars or strains, neither of these metals has of late years found any extended use. The only other metal formerly known possessed of sufficient tenacity for such purposes was wrought-iron, which, in the course of time, has gained for itself so high a reputation that much prejudice has to be overcome before people will use anything else. In fact, iron-men are noted for their conservatism, and we readily admit that they ought to be conservative, when we consider the vast interests committed to their charge, often involving numerous human lives, as well as large amounts of money.

By the pneumatic or Bessemer process it is doubtless possible to make a metal resembling steel so closely that for many purposes it could be substituted for it. But in practice we find that what is actually made differs very widely from steel, and comes into competition rather with wrought-iron. Let us keep this point fully in view, while we compare the relative merits of wrought-iron and Bessemer metal. Everybody knows that it is impossible to handle very large masses of iron at once in a puddling furnace; and hence, if we want a heavy piece of wrought-iron, it is necessary to weld together two or more blooms in order to get it. It is also notorious that blooms are too likely to contain slag and other impurities, to be directly used in the manufacture of wrought-iron articles. They must first be subjected to the process of hammering, drawing out, and welding.

However carefully the process of welding is conducted, there is always a possibility of leaving the welds imperfect, and hence the product, though externally perfect, is subject to flaws in the interior, which render it liable to fracture under strains which it ought to resist with ease. Bessemer metal, however, can be cast in ingots of 5 tons each, free from slag, and capable of being used directly for the manufacture of heavy articles. In this case, instead of flaws from imperfect welding, such as occur in wrought-iron, we are liable to find defects in the form of bubbles. Practically, it has been found that bubbles are much more frequent close to the periphery of the ingot than nearer the centre, so that the external appearance of a Bessemer ingot furnishes us with a correct idea of its internal condition. It is, moreover, asserted that when bubbles occur in the interior, they are free from rust, and present clean metallic surfaces, which weld together perfectly when the ingot comes to be drawn out. A correspondent of the "Maschinen Constructeur" says that he has seen Bessemer metal used with great advantage for making the piston-rods of steam hammers which were used for hammering steel. Wrought-iron pistons and piston rods of the same dimensions were used up in a short time, by the change of the iron from a fibrous to a granular structure, in consequence of the repeated concussions to which they were subjected. Bessemer metal has also been used for locomotive axles with excellent results. Its use for this purpose, as well as for boiler plates, is continually increasing in Europe, though we have not yet heard of its application to either purpose in this country. The fact that it resists the oxidizing effects of a flame much better than wrought iron is a strong argument for its use in boilers. It is only about 13 years since the first introduction of Bessemer metal, and though its adoption for rail-making has been contested, step by step, until it proved itself far superior to other iron, it is now almost universally commended for that purpose.

It is scarcely to be expected, however, that because its merits for rail-making has

been recognized, its other uses will meet with no opposition. Boiler-makers, for example, who have been all their lives accustomed to the employment of wrought-iron, will not discontinue to use it at once —though in the long run a superior material is certain of adoption. A large number of the boiler explosions of which we hear so often, are doubtless due to the partial destruction of the iron by oxidation, in boilers which were originally equal to the task imposed upon them. This fact was fully proved in England, by evidence recently given before the committee appointed by Parliament to inquire into the cause of the alarming number of boiler explosions occurring annually in that country, and to suggest remedies. The sulphur contained in the soft coal, which is used almost universally in England, may cause the destruction of the iron to take place more rapidly there than it would in this country, where so much anthracite and wood are used. Still, this destruction is, in a great measure, due to the oxidizing effects of the flame, which Bessemer metal resists much better than wrought-iron. So that the conclusions of the English committee are almost equally applicable to this country. This, in connection with its greater tenacity, would seem to recommend especially the use of Bessemer metal for boilers, and will doubtless lead, before long, to its experimental adoption for that purpose in this country.

LECTURE ON STREAM LINES AND WAVES IN CONNECTION WITH NAVAL ARCHITECTURE.*

By W. J. MACQUORN RANKINE, C.E., LL.D., F.R.SS. L. AND E.

From "Engineering."

The lecturer stated that his object was to give a brief summary of the results of some applications of the mathematical theory of hydrodynamics to questions regarding the designing of the forms of ships, and the mutual actions between a ship and the water in which she floats. The art of designing the figures of ships had been gradually developed by processes resembling those called "natural selection" and the "struggle for existence," in the course of thousands of years, and had arrived in skilful hands at a perfection which left little more to be desired, when the object was to design a ship that should answer purposes and fulfil conditions which had previously been accomplished and fulfilled in the course of practical experience. But cases now frequently arose in which new conditions were to be fulfilled, and purposes to be accomplished beyond the limits of the performance of previous vessels; and in such cases the process of gradual development by practical trials made without the help of science was too slow and too costly, and it became necessary to acquire and to apply scientific knowledge of the laws which regulate the action of the vessel on the water and of the water on the vessel. Amongst the questions thus arising were the following:—What ought to be the form of the immersed surface or skin of a ship in order that the particles of water may glide smoothly over it? And the form of such a surface being given, how will it affect the motions of particles in its neighborhood, and what mutual forces will be exerted between the particles of water and that surface? Practical experience, unaided by science, answers the first question by saying that the surface ought to belong to a class called "fair surfaces"—that is surfaces free from sudden changes of direction and of curvature—of which various forms have in the the course of ages been ascertained by trial, and are known to skilful shipbuilders. That answer is satisfactory, so far as it goes; but in order to solve problems involving the mutual actions of the ship and the water something more is wanted, and it becomes necessary to be able to construct fair surfaces by geometrical rules based on the laws of the motion of fluids, and to express their forms by algebraic equations. There were many very early attempts to do this; but not being based on the laws of hydrodynamics they resulted merely in the finding of empirical rules for reproducing when required, forms that had previously been

* British Association.

found to answer in practice, and did not lead to any knowledge of the motions of the particles of water or of the forces exerted by and upon them; and they had little or no advantage over the old process of modelling by the eye and hand, and of "fairing" the lines with the help of an elastic rod called a "batten." As regards this process, indeed, the mathematical methods about to be referred to are to be regarded, not as a substitute for it in designing the form of a ship, but as a means of arriving at a knowledge of the mutual actions between her and the water, which the old process is incapable of affording. The earliest method of constructing the figures of ships by mathematical rules based on hydrodynamical principles was that proposed by Mr. Scott Russell about twenty-five years ago, and since extensively practised. It consisted in adopting for the longitudinal lines of a ship curves imitated from the outlines of waves in water. The motions which surfaces formed upon this model impressed on the water were known to a certain degree of approximation. Those "wave-lines," however, although they were very fair curves in the sense already mentioned, were by no means the only fair curves, but were only one class out of innumerable classes of curves having the property of gliding smoothly through the water; and it was well-known in practice that vessels had proved successful whose lines differed very widely from wave-lines. It was therefore desirable that methods should be devised of constructing by mathematical rules, based on the laws of the motion of fluids, a great variety of curves possessing the property of fairness, and not limited to the wave-line shape. Such had been the object of a series of researches that had been communicated to the Royal Society at different dates since 1862. They related to the construction of what it has been proposed to call stream-lines. A stream-line is the track or path traced by a particle of water moving in a smoothly and steadily flowing current. If, when a ship is gliding ahead through the water with a certain speed, we imagine the ship to be stationary, and the water to be flowing astern past the ship in a smooth and steady current with an equal average speed, the motions of the ship and of the particles of water relatively to each other are not altered by that supposition; and it becomes evident that if the form of surface of the skin of the ship has the property of fairness, all the tracks of the particles of water as they glide over that surface are stream-lines, and the surface itself is one containing an indefinite number of stream-lines; or, as it has been called, a stream-line surface. It is also to be observed that when we have deduced from the laws of the motion of fluids the relations which exist between the forms of the stream-lines in different parts of the current, and between those forms and the velocities of the particles as they glide along different parts of those lines, we know the relation between the form and speed of a ship whose surface coincides with a certain set of those stream-lines, and the motions of the particles of water in various positions in the neighborhood of that ship. The lecturer then proceeded to explain and to illustrate by diagrams, the methods of constructing stream-lines. These methods were based upon the application to stream-lines in a current of fluid, of a mathematical process which had previously been applied by Mr. Clerk Maxwell to lines of electric and magnetic force. A current of fluid is represented on paper by drawing a set of stream-lines, so distributed, that between each pair of them there lies an elementary stream of a given constant volume of flow. Thus, while the direction of flow is indicated in many given parts of the current by the direction of the stream-lines, the velocity of flow is indicated by their comparative closeness and wideness apart, being evidently greatest where those lines lie closest together, and least where they are most widely spread. If, upon the same sheet of paper, we draw two different sets of stream-lines, these will represent the currents produced in one and the same mass of fluid by two different sets of forces. The two sets of lines represent a network; and if, through the angles of the meshes of that network we draw a third set of stream-lines, it can be proved from the principle of the composition of motions that this third set of lines will represent the current produced in the same mass of fluid by the combinations of the forces which, acting separately, would produce the currents represented by the first two sets of stream-lines respectively. The third set may be called the resultant stream-lines, the first two

the component stream-lines. Suppose, now, that a third set of component stream lines are drawn representing the current produced by a third set of forces, this will form a net-work with the previously drawn resultant stream-lines ; and a set of lines drawn through the angles of the meshes of this new net-work will represent the resultant current produced by the combination of the three sets of forces, and so on to combinations of any degree of complexity that may be required. In order to draw a system of stream-lines suited for the longitudinal lines of a ship, three sets at least of component stream-lines must be combined. One of these is a set of parallel straight lines, representing an uniform current running astern with a speed equal to the actual speed of the vessel. A second set consists of straight lines radiating from a point called a focus, in the fore part of the vessel, and they represent the diverging motion that is produced by the ship displacing the water near her bows. The third set of component stream-lines consists of straight lines converging towards a second focus in the after part of the vessel ; and they represent the motion of the water closing in astern of the ship. The resultant stream-lines thus produced present a great variety of forms—all resembling those of actual ships, having all possible proportions of length to breadth, and all degrees of bluffness and fineness at the ends, ranging from the absolute bluffness of a sort of oval to a bow and stern of any degree of sharpness that may be required. It has been proposed to call stream-lines of this sort *oögenous neoïds*, that is, ship-like lines generated from an oval, because any given set of them can be generated by the flow of a current of water past an oval solid of suitable dimensions. The properties of these curves were investigated in 1862. They have, however, this defect, that the absolutely bluff ovals are the only curves of the kind that are of finite extent ; all the finer curves extend indefinitely in both directions ahead and astern ; and in order to imitate the longitudinal lines of a finer ended vessel a part only of some indefinitely extended curve must be taken. In 1870 an improvement in the construction of such curves was made by which that defect was overcome ; it consisted in the introduction of one or more additional pairs of foci, involving the combination of at least five sets of component stream-lines. By this device it is possible to imitate the longitudinal lines of actual vessels by means of complete closed curves without using portions of indefinitely extended curves ; and thus the knowledge of the motion of the particles of water, as shown by the stream-lines that lie outside the closed lines representing the form of the vessel, becomes more definite and accurate. The lecturer mentioned that the idea of employing four foci and upwards had been suggested to him by the experiments of Froude on the resistance of boats modelled so as to resemble the form of a swimming bird, for which purpose stream lines with four foci are specially adapted. It has been proposed to call such lines *cygnogeneous neoïds*, that is, ship-like curves of shapes like that of a swan. In such curves, when adapted to fine-ended ships, the outer foci, that is, the foremost and the aftermost, are situated in or near the stem and sternpost of the vessel, which are represented in plan by small horseshoe-like curves, as if they were rounded off at the corners, instead of being square, as in ordinary practice. The inner foci are situated respectively in the fore and after body. When the foci of the longitudinal lines of a vessel have been determined, the proportion borne by the aggregate energy of the motion impressed on the particles of the water to that of the motion of the vessel herself, can be approximately determined ; and it is found to range in different cases from one-half to the whole of the energy of the ship. A convenient empirical rule for the approximate displacement of a ship with a true stream-line surface has been incidentally obtained in the course of these investigations; it is as follows :—Find the positions of the two cross sections whose areas are each equal to one-third of the midship section, multiply five-sixths of the longitudinal distance between these cross sections by the midship section ; the product will not differ by more than 2 per cent. of its amount from the actual displacement if the ship is bounded by a true stream-line surface. This has been found by trial to hold for various forms and proportions ranging from a sphere to a very sharp wave-line. The lecturer next proceeded to explain the bearing of some of the mechanical properties of

waves upon the designing of vessels especially when these properties are taken in combination with those of stream-lines. It had long been known that ships in moving through the water were accompanied by trains of wave, whose dimensions and position depended on the speed of the vessel, but the first discovery of precise and definite laws, respecting such waves was due to Mr. Scott Russell, who published it about twenty-five years ago. The lecturer now described, in a general way, the motions of the particles of water in a series of waves, and illustrated them by means of a machine contrived for that purpose. He showed how, while the shape of the wave advances, each individual particle of water describes an orbit of limited extent in a vertical plane. The periodic time of a wave, its length, the depth to which a disturbance bearing a given ratio to the disturbance at the surface of the water extends, and the speed of advance of the wave, are all related to each other by laws which the lecturer explained. He then stated that Mr. Scott Russell had shown that when the vessel moved no faster than the natural speed of advance of the waves that she raised, these waves were of moderate height, and added little or nothing to her resistance; but when that limit of speed was exceeded, the waves, and the resistance caused by them, increased rapidly in magnitude with increase of speed. His own (Professor Rankine's) opinion regarding these phenomena was, that when the speed of the vessel was less than or equal to the natural speed of the waves raised by her, the resistance of the vessel consisted wholly, or almost wholly, of that arising from the friction of the water gliding over her skin; and he considered that this opinion was confirmed by the results of practical experience of the performance of vessels. The wave motion, being impressed once for all on the water during the starting of the vessel, was propagated onward like the swell of the ocean, from one mass of water to another, requiring little or no expenditure of motive power to keep it up. But, when the ship was driven at a speed exceeding the natural speed of the waves that she raised, those waves, in order to accompany the ship, were compelled to spread obliquely outwards instead of travelling directly ahead; and it became necessary for the vessel, at the expense of her motive power, to keep continually originating wave motion afresh in previously undisturbed masses of water; and hence the waste of power found by experience to occur when a ship was driven at a speed beyond the limit suited to her length. This divergence, or spreading sideways of the train of waves, had a modifying effect on the stream-lines representing the motions of the particles of water. It caused them, in the first place, to assume a serpentine form, and then, instead of closing in behind the ship to the same distances from her course at which they had been situated when ahead of her, they remained permanently spread outwards. In other words, the particles of water did not return to their original distance from the longitudinal midship plane of the vessel, but were shifted laterally and left there, much as the sods of earth are permanently shifted sideways by the plough. The place of the water which thus fails to close in completely astern of the vessel, is supplied by water which thus rises up from below and forms a mass of eddies rolling in the wake of the ship. This was illustrated by a diagram. Lastly, the lecturer explained the principles according to which the steadiness of a ship at sea is affected by waves; and the difference between the properties of steadiness and stiffness. The mathematical theory of the steadiness of ships had been known and applied with useful results for nearly a century; but in the course of the last few years it had received some important additions, due especially to the researches of Mr. Froude on the manner in which the motions of the waves affect the rolling of the vessel. A stiff ship is one that tends strongly to keep and recover her position of uprightness to the water. A steady ship is one that tends to keep a position of absolute uprightness. In smooth water these properties are the same; a stiff ship is also a steady ship in smooth water. Amongst waves, on the other hand, the properties of stiffness and steadiness are often opposed to each other. A stiff ship tends as she rolls to follow the motions of the waves as they roll; she is a dry ship; but she may be what is called uneasy through excessive rolling along with the waves. The property of stiffness is possessed in the highest degree by a raft, and by a

ship, which, like a raft, is very broad and shallow, and whose natural period of rolling in smooth water is very short compared with the periodic time of the waves. In order that a ship may be steady amongst waves, her natural period of rolling should be considerably longer than that of the waves, and in order that this property may be obtained without making the vessel crank, the masses on board of her should be spread out sideways as far as practicable from the centre of gravity; this is called "winging out the weights." A vessel whose natural period of rolling in smooth water is only a little shorter or a little longer than that of the waves, has neither the advantages of stiffness nor those of steadiness, for she rolls to an angle greater than that of the slope of the waves; and her condition is especially unsafe if her natural period of rolling is a little greater than that of the waves; for then she tends to heel over towards the nearest wave crest, to the danger of its breaking inboard. This is called rolling "against the waves." The most dangerous condition is that of a vessel whose period of rolling in smooth water is equal to that of the waves that she encounters; for then every successive wave makes her roll through a greater and greater angle, and under these circumstances no ship can be safe, how great soever her stability. All these principles have been known for some years, through Mr. Froude's researches. The lecturer exhibited a machine which he had contrived for illustrating them, in which the dynamical conditions of vessels of different degrees of stiffness and steadiness were approximately imitated by means of a peculiarly constructed pendulum, hanging from a pin whose motions imitated those of a particle of a water disturbed by waves. He concluded by thanking the members of the Association for the attention with which they had heard him.

THE Elevated Railway in Greenwich street is not at present in operation. It is currently reported that some motive power is to be substituted for the stationary engine and endless rope.

THE caisson of the East River Bridge is sinking gradually to its place. It is now at the depth of 36 feet. The depth proposed is 45 feet below high water.

RAILWAY NOTES.

FROM the "New York Tribune" of Oct. 31, we extract the following historical reminiscences of the railway locomotive:

Eighteen hundred men make a locomotive engine in one day—boiler, cylinders, frame, driving-wheels, truck, stack, cab, pilot, and tender, complete—the speed of 40 miles an hour and the power of a thousand tons created in a day.

On the 25th of April, 1831, a miniature locomotive engine, drawing two cars with seats for four persons, was set in motion on a track laid in the rooms of "Peale's Museum," in the city of Philadelphia. Great numbers of people, not only from the city but from distant parts, visited the Museum to witness the performances of this wonderful machine. Previous to that date only three attempts had been made in the construction of locomotives by American mechanics. Two engines, the "Phœnix" and the "West Point," had been built at the West Point Foundry, in 1830, for the South Carolina Railroad, and a third, the "De-Witt Clinton," for the Mohawk and Hudson Railroad, was completed in the spring of 1831. Two locomotive engines had been imported from England, one in 1828, for the Carbondale and Honesdale Railroad in Pennsylvania, and another for the Mohawk and Hudson Road, in 1830. The little engine amusing the visitors at Peale's Museum was the invention and work of Mr. Matthias W. Baldwin, then a skilful and enterprising mechanic of Philadelphia.

The following year Mr. Baldwin received an order from the Germantown Railroad Company for a locomotive for their road.

The difficulties to be overcome required an unusual degree of persistence and a masterly skill. Mr. Baldwin proved equal to the task, and in six months produced the "Ironsides." Its success was complete, the reputation of the builder was assured, and the foundation of a new branch of industry established.

Up to 1834, five engines had been built at this little shop; the next year produced fourteen, and the next forty. Now the Baldwin Locomotive Works can produce a complete locomotive for every working day in the year.

The improvements upon the manufacture of 1834 are of course almost numberless. Many of these are due to the maker of the "Ironsides;" and quite a large proportion of the most valuable were not reserved to the inventor's own use by patents, but were given to the public; more reliance being placed in superiority of skill and workmanship than in Letters Patent, to maintain the leadership in American production.

The Baldwin Locomotive Works are located on North Broad street, Philadelphia, and occupy the greater part of three blocks, from Pennsylvania ave. to Spring Garden st., and an area of 240,000 square feet. On the centre of the Broad street front stands the old shop, three stories in height, erected by Mr. Baldwin in 1834. Here are the offices, store-room and drawing department, and also what is called the Hamilton street shops, including boiler shop, smith shop, brass foundry, "first, second, and third story machine shops," and pattern loft. South of this building is the Willow street shop, where cylinders and frames are finished, and tanks, trucks, stacks, and cabs are made. Adjacent to this building on the west is a

brick building 266 ft. long, 60 ft. deep in the central part, and with two wings 108 ft. deep at either end. The central part of the building and the east wing are used for the iron foundry, where all the cast-iron work used about a locomotive, except the truck wheels, is made. The west wing is used as a hammer shop. One large steam hammer, rated at 5,000 lbs., is in constant use here, working up scrap and bar iron into blooms from which the engine frames are made. On the north side, beyond Buttonwood street, is the erecting shop, whither all parts tend, and whence complete locomotives emerge. Two large buildings and a lot of ground, detached from the main establishment, are employed as a blacksmith shop, stable, and storage room, not enumerated in the above.

The different varieties of locomotives usually manufactured in the establishment are technically designated in the Baldwin classification by certain letters and numbers. The letters indicate the plan or kind of engine; the numbers, the size or weight. The combination of the letters and numbers indicates precisely the class. To explain more clearly, the letter B is used to designate all engines having a single pair of drivers; C, those with two pairs of drivers; D, those with three; and E, those with four pairs of drivers connected. Then certain numbers, now merely arbitrary, but originally intended to indicate the weight of the machine in gross tons, are joined with the letters, and the combination designates a particular plan and size of locomotive. The ordinary type of the American locomotive, it is well known, is an engine on eight wheels, four of them under the fire-box part of the machine, and acting as "drivers," and four smaller wheels combined into a truck to carry the forward part of the engine. Such an engine in the Baldwin technicology, would be a "C" engine, by virtue of its having *two pairs of drivers connected.* If its cylinders are 16 in. in diameter, the boiler must be large enough to furnish them with steam, and all the other parts of the machine must conform in size. The aggregate weight of the engine is accordingly governed by the dimensions of the cylinders. Now the figures 27½ indicate these facts. We have then the combination 27½ C to designate a locomotive with eight wheels, four of them drivers, with cylinders 16 in. in diameter, and a certain aggregate weight for the whole machine. In like manner all the other classes of engines are appropriately designated.

From these classes and varieties the customer makes choice. Perhaps because of some special service, special modifications are required; these are noted and the price is agreed upon. The purchaser goes to his home, and his order to the "drawing department." Here the engine is, as it were, analyzed and dissected. The proposed machine, existing as yet only in imagination, must be composed, it is found, of a certain definite number of parts. The smith shop accordingly receives a written order, in a book provided for the purpose, to make the forgings, the foundry the castings, the boiler shop the boiler, and so on. The several machine shops also have their orders to fit up and finish these several parts which may come to them from the other departments. But not only is the bare order to do the work thus made, the manner in which it is to be done is also provided for. Drawings and patterns are already in existence for every one of the parts to be constructed, unless the engine is of a class never before built. These drawings and patterns all have their separate distinguishing numbers. Each order for the production of any part, or for the finishing or fitting of it, bears also the number of the drawing or pattern to which the work is to be done. These order-books and the necessary plans and patterns now go to the several departments, and with the fulfilment of the orders which they communicate must result all the parts required for the complete locomotive.

Every department of this great establishment is perfectly organized. Materials and men are classified. Every piece in its transition from crude stock to finished work, has its appointed place, and workmen. Everything is tested rigorously by exact measurement, so that broken parts of working engines may be supplied from the verbal description.

During the past twelve months, 271 complete locomotives have been sent from this shop, as follows: In October, 1869, 22; in November, 26; in December, 22; in January, 1870, 21; in February, 21; in March, 21; in April, 21; in May, 23; in June, 23; in July, 23; in August, 24; in September, 24. This is certainly a decided progress from the five engines turned out by Mr. Baldwin in 1835. But the progress which has been made in the methods of construction, resulting in increased efficiency, strength, speed, economy in fuel, and in repairs, is no less wonderful. The archives of the establishment, containing, as they do, communications covering a period of thirty-five years, and in the handwriting of railroad managers, engineers, and master mechanics, are not only a reflex of the general progress of railroad practice, but bear strong testimony to the efficiency and durability, and superior workmanship, for which the Baldwin engine has achieved an enviable reputation.

We cannot leave this subject without a word of comment on the lesson it teaches as to the value of American manufactures and the importance of fostering and protecting them.

Here is an establishment, the value of the finished products of which, in 1869, was $3,430,018.84. Of this sum, $1,068,388.20 was expended for labor, giving employment to 1,600 or 1,700 men, and, if we allow 5 persons to a family, furnishing a support for a population of 8,000 to 9,000 souls – no inconsiderable portion of the population of Philadelphia. But, further, the remaining two and a half millions represent the amount expended for materials, for tools, for railroad, canal, and steamer freights, for the innumerable incidental expenses of carrying on such a business, and for the return on the capital invested. But of this expenditure for material, bought and used in the manufacture of locomotives, all, without an exception, save some few articles not produced in this country, are exclusively American products or American manufactures. American boiler plate, American steel, American pig and bar iron, American lumber, American coal, American copper, and American brass, are the principal materials from which the Baldwin Locomotive Works construct their machines. All these articles, as they come to the works, represent in their cost price principally labor, and American labor at that—labor in mining coal, in smelting iron, in rolling boiler plate, in cutting and sawing lumber, etc. If we go back to the absolute first cost, or the royalty, for the coal and ore in the ground, and the lumber in the forests, as we logically may, we shall have but a few thousand dollars as the original first cost for the raw material, which mined, smelted, cast, forged, planed, turned, finished, and polished, stands

finally on the books at an aggregate value of nearly three and a half millions of dollars, and in its various stages of transformation and progress has given employment to probably 6,000 men, and supported a population of 30,000 souls.

These facts speak for themselves. But still another consideration is to be added; America competes with England in the manufacture of locomotives for foreign countries. Baldwin engines are at work in Germany, in Canada, in Cuba, in Brazil, in Peru, and in the Argentine Republic, and have been placed there, if not at less cost, at least as cheaply as English locomotives could have been. But English iron is only a fraction of the cost of American iron, and English labor brings wages barely sufficient to keep soul and body together. English pig-iron costs to-day $14 to $16 per ton; American pig-iron, $32 to $33 per ton. With equal prices for locomotives and machinery in the two countries, what is the inference? Clearly, that while in Europe capital extorts the lion's share as its return, here, where wages and the cost of material are both so much higher, it is labor—adequately paid, making possible comfortable homes, education, self-improvement, self-respect, and an intelligent citizenship—which stands foremost in the value of the finished product.

IRON AND STEEL NOTES.

Mr. Wm Lewis, who has been for the past four years connected with the Spuyten Duyvil Rolling Mill Company, at Spuyten Duyvil, N. Y., as the superintendent of their mills, was presented by the employees of the Company, on the occasion of his retiring from the position, with a handsome gold watch and chain, on which was inscribed the following: "Presented by the employees of the Spuyten Duyvil Rolling Mill, to Wm. Lewis, Superintendent, as a token of respect. Oct. 29, 1870."

Mr. Lewis goes to Columbia, Pa., where he is to take charge of the Columbia Rolling Mill.

The Weardale Iron and Coal Company, England, have almost completed their two large blast furnaces at Weardale. The furnaces are 85 ft. in height, 26 ft. at the bosh, and 7½ ft. in the hearth. The body of each furnace rests on 12 cast-iron columns, capped by an annular plate. The furnaces are cased with wrought-iron plates, of uniform diameter to the top externally; they will be closed at the top by the cup and cone. The down-pipe to withdraw gas from each is 3½ ft. in diameter, joining to the main gas-tube, 5½ ft. in diameter; these are of wrought-iron, not lined internally. Immediately behind each furnace, six stoves with cast-iron pipes are built, in two rows. Between these rows the wrought-iron pipes to supply gas to the six stoves are fixed. Each stove contains 14 double cast-iron pipes, 16 ft. in length, placed in two rows; each pipe is 19 in. by 5 in. in section; the blast having to pass through one row of these pipes, or 14 lengths of single pipe, before it makes its exit. Each stove is provided with its own chimney; the main blast-pipe is 6 ft. in diameter. Behind the stoves one large coke-hopper is built for each furnace, and a gantry, under which limestone and other material is stocked. Behind this a line of five calcining kilns are in course of erection; these are 45 ft. in height, plated externally, 20 ft. inside diameter, and will have self-acting delivery at the bottom of the kilns. The top of these and the gantries are approached by locomotive roads. The furnace-lift is on the water-balance principle—one carriage ascends while the other descends. The water-tank is fixed 20 ft. above the platform level. Three blowing engines, acting independently, and non-condensing, are erected in one building. Each engine (the cylinders being vertical, the blowing-cylinder at top and the steam-cylinder under it) rests on two cast-iron standards.

These engines are from the works of Cochrane, Grove & Co., Middlesborough. Each blowing cylinder is 84 in., steam cylinder 40 in. in diameter, placed 6 ft. below the blowing cylinder; stroke 5 ft.; the trunk at the top of the steam cylinder is 18 in. in diameter; from this by a cross-head and two connecting rods, motion is given to the fly-wheel shaft, and two fly-wheels of 7 tons each, all within the standards. One eccentric gives motion to two piston valves. The extreme height of the engines from the foundation is 25 ft. The blowing-cylinders are enclosed with sheet-iron, and by means of a pipe to the outside of the building the suction-valves will draw air from the exterior. The engines are designed to go from 20 to 30 strokes per minute; at the ordinary rate of 20 strokes each engine will supply 7,600 cubic feet per minute, and at the maximum, 11,400 cubic feet. In the same building two engines are erected, to supply water for the furnace lift and the tuyeres; each engine works two double-acting pumps with a plunger. There are also two smaller engines erected to feed the boilers. Eight plain cylindrical boilers are being fixed, 75 by 5 ft., each suspended from five arched girders, resting on cast-iron pillars, 5 ft. in length. The boilers will be heated entirely with gas from the furnaces. The chimney is 130 ft. in height.—*Bulletin of Am. Iron and Steel Association.*

ORDNANCE AND NAVAL NOTES

Captain Harvey's Torpedo.—A most important and interesting trial of a sea torpedo was made on Monday, the 25th ult., in the offing at Plymouth. The Commander-in-Chief, Admiral Sir H. Codrington, K. C. B., Captain the Hon. F. A. Foley, Captain Jones, Captain Napier, Commander Harvey (the inventor), and other naval authorities were present on board the gunboat "Pigeon." The first torpedo on the port side, was used against the hulk "Sea Horse," the gunboat crossing her stern and the torpedo striking her port amidships about 10 ft. below the water line. No. 2 torpedo, on the starboard side, was towed against Her Majesty's brig "Squirrel," under canvas in the offing, and striking her on the port quarter, came up under her bows. No. 3, towing to starboard, was then brought down upon the turret-ship "Prince Albert," at shell practice, further out; the gunboat crossed the ship's bow, and the torpedo struck her port bow, 8 ft. under water, and passing under the bottom, came up on the starboard bow. With No. 4, to port, also used against the "Prince Albert," the tow-line passed over the ship and was allowed to run out to the end; the bight was then thrown clear and the torpedo came up from under the bottom. This was occasioned by no fault of the apparatus, but from want of speed in the gunboat at

the moment of collision. No. 5, to starboard, was used against the brig "Squirrel," and, striking her on the starboard bow at 8 ft. under water, came up under the starboard quarter. Several other attacks were then made on the turret-ship "Prince Albert," in every conceivable direction, and in almost every instance with complete success, as the capsule was found to be pierced after every contact, showing that had the torpedoes been loaded with an explosive compound the destruction of the vessels struck must have ensued. The trial, although quite sufficient to show the principle and accuracy of this formidable weapon, would have displayed its precision more prominently had the towing been performed by a faster vessel than the "Pigeon," which steams only six knots, whereas it should be a speed of eleven knots, at least, to insure good steerage to the torpedo and its sharp contact with the opposing vessel. The Russian Government are before us in adopting this terrible engine of war, as 20 of these torpedoes have already been supplied, and are being used for practice by the Russian war steamers on the Baltic. Several interesting experiments were also made with small quantities of explosive compounds, and by the results one could imagine the frightful effect of 100 lbs. (the torpedo's charge) exploding with upward tendency under a ship's bottom. The Commander-in-Chief and other officers went on board the turret-ship "Prince Albert" during a great part of the time, so as to witness the approach of the torpedo from this point of view.

THE LYMAN ACCELERATOR GUN.—Some time back we referred to the construction of the gun known as the "accelerator," in which a series of chambers were arranged at the side of the bore for containing charges of powder, which exploded in succession as the projectile moved along it towards the muzzle until the combination of the charges exerted their full force upon the base of the shot to throw or propel it. The gun tried was of small calibre, about 4 in. diameter, and this succeeded beyond the expectations of the company who were present to witness the trial. The success of the small one led the gentlemen interested in its production for field or battery purposes to endeavor to have one of a large size cast. Of course, many difficulties had to be overcome before they could venture to make the world acquainted with the fact that a large one was in hand, but after several failures, mainly due to unforeseen circumstances, they have had one cast weighing 10,175 lbs., and measuring 11 ft. 6 in. in length. This gun was tried in the United States a few miles below Reading, Pennsylvania, on the old proving ground.

The cannon was fired three times during the morning of June 29. The charges were as follows:

1st round, 1 lb. of powder in breech.
" 4 " " each pocket.
" weight of ball, 57 lbs.
2nd round, 1½ lbs. of powder in breech.
" 6 " " each pocket.
" weight of ball, 77 lbs.
3rd round, 2 lbs. of powder in breech.
" 8 " " each pocket.
" weight of ball, 100 lbs.

The powder used for the breech was navy mammoth powder, and that for the four chambers or pockets along the bore was navy cannon powder, of 1,495 initial velocity and 991 density, Dupont's make.

The last round was a full proof charge, as intended for this gun, the heaviest charge ever placed in a cannon of the same calibre. After each round the diameter of the bore was carefully measured, but not the slightest increase could be discovered. The gun has so far given entire satisfaction. The balls were fired into a sand bank backed by logs, among the latter of which the balls lodged themselves about 4 ft. from the ground. The cannon was placed on a skid, and the charges were so heavy that the gun vibrated for several minutes a distance of some 35 ft. after each charge.

On the 30th some further trials were made, which completely tested the strength of the gun. Two rounds, each with 30 lbs. of powder and a solid shot weighing 100 lbs. were fired. So far the gun is a complete success in all its parts. No perceptible enlargement has taken place in the bore, and no part of the gun has been strained or worn by the action of the powder-gas or the balls. The shot used on this occasion could not be found after the firing, they having passed through 18 ft. of moist sand and imbedded themselves in the barricade of logs beyond the sand.

We understand that in a few weeks the gun will receive further proof with a view to ascertain the distance it will throw a 100-lbs. shot. The calculation is that it will reach a range of ten miles, and pass through at short range a wrought-iron target 15 in. thick. The powder used in the breech or bottom of the bore is encased in copper, and the wad, which is 4½ in. thick, and made of bookbinder's heavy brown paper, is also attached to a copper plate.

The thickness of the metal of the gun along the pockets at the reinforce, is equal to the calibre, and along the neck, near the end of the muzzle, 3½ in. The thickness of the metal of the pockets is one calibre.

This cannon has already been put to a severer test by the extraordinarily heavy charges, than any other gun heretofore made. In the Parrott rifled cannon, one of the most successful guns, only 8 lbs. of powder and a ball weighing 80 lbs. are used, while in this one 34 lbs. of powder and a ball weighing 100 lbs. are employed. Both these guns are rifled and are of the same calibre and weight. It was the universal opinion, excepting among the projectors of the gun, that the Lyman cannon would prove a failure, that it could not possibly stand the heavy proof charges destined for it.

The Lyman accelerator gun performed handsomely while under proof, and this fact may cause a revolution in the mode of constructing heavy ordnance.

The trials were under the directorship of Alban C. Stimers of New York, late naval engineer in the U. S. Navy, by whom the cannon was designed; Messrs. Samuel K. Wilson, of Trenton, N. J.; James R. Haskel, of New York; Captain W. R. M'Manus, and W. H. Robinson.

Further trials are ordered by the U. S. Government, and when these are completed the gun will be brought to England to be tested by the War Office authorities.—*Mechanic's Magazine.*

COLONEL MAXWELL. R. A., Superintendent of the Cossipore Gun Foundry, after comparing the French and Prussian field-guns, in a letter to the "Times," concludes by saying:—"I fearlessly and dispassionately assert that the 9-pounder muzzle-loading gun which we have lately adopted is the most powerful field-gun of its size in Europe; that

in a few weeks we shall be provided with a trustworthy concussion fuse for bursting both common shell and shrapnel on graze when the ground is favorable; that we have already the best time fuse in existence for bursting shells in the air, under proper circumstances; that this gun and its ammunition can in nowise go wrong, and that we may confidently send it into the field to meet any field-gun in existence of its size. But we must learn to fire deliberately, and apply reason, based on experience, in teaching our gunners their art." The "Times," in a long article on the subject of field artillery as illustrated by the operations of the present war, asks:—"Are we to rest satisfied with 12-pounders as the highest calibre of British field artillery capable of being carried with an army making forced marches, and able to be transported rapidly from place to place on the field of battle? If so, we should find ourselves opposed by artillery of higher calibre in case of war with either Prussia, Austria, or Russia. The Prussians have 15-pounders, the Austrian field-battery gun throws a projectile of nearly 16 lbs. weight, and the Russians have a field piece weighing little more than 12 cwt., considerably less than the English smooth-bore 9-pounder which we had in the Crimea, yet throwing a projectile of more than 25 lbs., with a velocity of 1,050 ft. per second."

ENGINEERING STRUCTURES.

New Bridge across the Mississippi.—From a late Detroit paper we make the following extract:

A short time since, the Detroit Bridge and Iron Company were awarded the contract for building an iron railroad bridge at Hannibal, Mo., over the Mississippi river, the contract price being about half a million of dollars.

The bridge crosses the Mississippi river at the city of Hannibal, Mo., and will connect the lines of railway built and being built to the river at that point. It is being constructed in the interests of four lines of railway: The Toledo, Wabash & Western, extending from Toledo, Ohio. to the east side of the Mississippi river at Hannibal; the Hannibal & Naples railroad, which is leased to the T., W. & W. railway and forms the western end of the line as above; the Hannibal and Moberly railroad, now being built from Hannibal, westward, to connect with the North Missouri railroad at Moberly; and the North Missouri railroad, extending from Moberly westward to Kansas City, connecting there with the Kansas Pacific and the various other lines of railroads in Kansas. All of the roads mentioned above are complete and in operation except the Hannibal & Moberly, which is now being rapidly constructed and will be finished within a year. A glance at the map will show the directness of the great through line thus formed between the East and the West, and the important influence it must exert as an artery of the national commerce.

No location on the Mississippi river could be selected more favorable for bridge purposes than at Hannibal. The channel is narrow, well defined, direct, and permanent. The river bed is well adapted for reliable and economical foundations, and the current is not rapid.

The precise point selected, after careful surveys, is about half a mile above the central part of the city. Here the river is hemmed in on the west by a high, precipitous, rocky bluff, along which runs the main channel, and on the east, a wide, flat bottom land spreads out to the opposite bluffs, about five miles away. Through this bottom wind many bays and sloughs, so called, through which the water in freshets finds abundant passage.

The bridge proper consists of four fixed spans of 180 ft. each: one fixed span of 250 ft.; one pivot draw span of 360 ft.; and one fixed span of 250 ft., in the order named, a total of 1,580 ft.

The masonry of piers and the foundations thereof will be of the best character. The west abutment is bedded on the solid rock. From thence, going eastward, the rock dips gradually, so that while it is exposed to the surface on the west side of the river, on the east side it is about 80 ft. below the surface. This is overlaid by sand, so that in the main channel the depth of water at the lowest stage is about 24 ft., and gradually decreases thence to each shore. The difference between high and low water is 22 ft. At high stage the bottom lands on the east side of the river are overflowed, and the surface of the water then is several miles wide.

The west pier and the massive pivot pier adjoining are placed upon piles driven through the sand to a firm bearing on the solid rock. The other piers and the east abutment are also placed upon piles, but these do not reach the rock. To prevent scouring, each pier and its foundation will be protected by riprap.

Each pile is to be so firmly driven as not to move more than one-quarter of an inch at the last blow of an iron hammer weighing 2,500 lbs. falling upon it from a height of 25 ft. The number of piles under the pivot pier is about 200, and under the other piers about 70 each. They will be driven into the sand about 22 ft., thus requiring piles from 40 to 50 ft. in original length. These are all of oak, hickory, or other approved hard wood, perfectly straight and sound, and not less than 8 in. in diameter at the small end. After being thus driven, they are cut off truly level at the bottom of the river, and the sand dredged away about their heads for a few feet in depth, the hole thus made in the river bed being filled with concrete.

Upon the heads of the piles thus placed, and the solid concrete bed surrounding them, the masonry is lowered in caissons or by screws. This process obviates the necessity of the old-fashioned expensive and dangerous coffer-dam, and foundations are thus placed with comparative ease and certainty in a depth of water that would have proved heretofore an almost impracticable obstacle to the engineer.

Upon the piers and abutments thus built, will be placed the iron superstructure. This being intended for both railway and highway travel, will be 18 ft. wide in the clear. The floor is laid on the bottom of the bridge, so that while being used for the passage of a train, vehicles and horses are of course excluded.

The Hannibal bridge will be substantially of wrought-iron throughout—the top chords of the fixed spans only being of cast-iron. The trusses of the 180-ft. spans are 23 ft. high; of the 250-ft. spans, 25 ft. high, and of the 360-ft. draw span, 26 ft. high at the ends and 34 ft. high at the centre. The respective trusses are divided into panels of about 13 ft. each. The general plan is that known as the Whipple or quadrangular truss, with parallel chords, inclined end braces, vertical posts and diagonal tie rods, the latter passing over two pan-

els each. The iron work is all manufactured at the Detroit Bridge and Iron Works, in this city. The cast-iron is from the best quality of No. 1 Lake Superior charcoal pig. The wrought-iron is guaranteed to be of the best bridge iron, and is all subject to thorough tests in a hydraulic press, all lots from which bars, selected at random, shall break under a tensile strain of 50,000 lbs. per square inch of sectional area, being condemned. After manufacture, and before being placed in the bridge, every bar is placed in the hydraulic press and subjected to an actual tensile strain of 20,000 lbs. per square inch, and while under such actual stress is to be struck several sharp blows with a hammer; and if any show permanent set or any defect whatever under this treatment they are to be condemned. These are very severe tests and only to be endured by the very best iron. The provisions for and the making of such elaborate and complete testing involves great expense and care, but in no other way can perfect materials and work be assured.

The dimensions of the various parts of the bridge are proportioned on the specifications; that a moving load over the bridge of 2,500 lbs. per lineal foot (in addition to the weight of the structure itself, and the flooring and tracks thereon) shall bring on no part a greater strain than one-fifth of its ultimate capacity. Thus, a 250 span with the flooring and tracks thereon, weighs about 260 tons. A moving load of 2,500 lbs. per lineal foot will amount to about 312 tons, which is considerably more than equal to a train of the heaviest locomotives, covering the entire structure. The two together are 572 tons, which is the greatest assumed load that can ever be placed upon the bridge. The factor of safety being 5. gives as the ultimate strength of the bridge 2,860.

The bridge is by contract to be complete and ready for use by August 1, 1871, but it is hoped by the application of extraordinary diligence and energy to anticipate that date.

The amount of materials required for the work embraced in the contract is about as follows:—400,000 lineal feet of piles; 1,000,000 ft. (board measure) of timber and lumber; 10,000 tons of masonry; 10,000 tons of riprap; 4,000 tons of concrete; 1,350 tons of iron.

THE NEW BRIDGE AT ALBANY.—The new iron bridge at Albany, which will open the second great highway over the Hudson, promises to be a very creditable engineering success. Across the main channel of the river are four piers, with 185 ft. span, and with a draw in the centre 272 ft. long and 185 ft. from the pier. Across the basin there are seven spans of 70 ft. each, making the total length of the bridge, including the approaches at either end, 1,550 ft. In height the bridge will be 30 ft. above low-water mark. Across the main channel of the river the bridge will be perfectly level, but after leaving the shore pier on this side there is a slight downward grade. The entire structure is to be of iron of the best quality. It will be provided with double tracks for railroad purposes, and on either side will be a foot bridge 6 ft. wide for the accommodation of pedestrians. The swing bridge in the middle is to be constructed on the most approved principle, and will be operated by steam power, applied so as to move it quickly and with mechanical precision. Two piers of the structure are already completed on the Greenbush side, and work has been begun on all the others. There are now about one hundred mechanics employed on the work, which is to be completed about July or August, 1872. When completed it will be used exclusively for passenger travel, and all freights will be sent across by the old bridge, according to the original plan of the Company. Messrs. Kellogg, Clark & Co., of Philadelphia, are contractors for the iron work. Its total cost will be about $1,000.000, and its projectors claim for it a permanent rank among the finest structures of its kind in the world. Our engineers are making great progress in the art of bridge building, and the United States will soon lead the world in new experiments in this important science.—*Iron Age.*

THE "HODGSON" TRAMWAY AT BRIGHTON.—We understand that the Wire Tramway Company intend removing the experimental length which has been working so successfully on the Downs at Brighton since May last. Those persons who have not already seen it at work should do so before the end of this month, or tney will lose the opportunity. It will be remembered that it was erected to test the capabilities of the system for moving small loads of minerals or farm produce with expedition and at small cost from one place to another over hilly districts. The rope is an endless out-and-home one of ten miles, supported on posts at elevations varying from 37 to 75 ft. above the ground. The loads are placed in boxes, which can be hooked on to the rope at any point by hand, and run off at any point, by small wheels with which the hook blocks are provided, running upon plates or siding rails, so that the boxes can be emptied of their contents. The invention has met with great success abroad, and we have recently heard that the Government of Turkey have decided to erect one or two lengths in that territory.

TELEGRAPHIC COMMUNICATION WITH CHINA.—There is now a good prospect that, before the end of another year, the Chinese coast will be brought within the circuit of telegraphic communication. The wealthy British corporation known as the "Great Northern Telegraph Company," has undertaken the construction of such a line, and the cable of which it is to be composed is already shipped on board the Danish screw frigate, Tordenskjold, which was chartered for the purpose nearly a year ago. The line will consist of 685 nautical miles of main cable, 272 miles of intermediate, 111 miles of ordinary shore end, and 30 miles of heavy shore end—1,098 miles in all, which were manufactured at Charlton, on the Thames, by Messrs. Siemens Bros. The Tordenskjold, which left for China during the month of June last, took the first section of this line, the propeller steamers Great Northern and Cella carrying the remainder. Should these vessels reach their destination in safety, the submarine cable uniting Hong Kong and Shanghai with the East India telegraph system, and thus, indirectly, with Europe and America, will soon be an accomplished fact.

The successful completion of this line will offer better facilities than any which now exist for communication between China and all parts of the world, and the people of this country will share in the advantages of the improvement. But such a line, which can only be made available for the transmission of messages following the most indirect of all possible routes to the East, will not long be adequate to the accommodation of the business which, even at the high rates which will necessa-

rily be charged, it will attract. What is needed is a cable extending from California to the east coast of China, and should such a line be built, there is no doubt that it would at once command a large and profitable business. The completion of this final link in the chain of circumterrestrial telegrapic communication is an undertaking well worthy of the enterprise of the American capitalists to whom the right to lay a cable across the Pacific properly belongs. A proposition to grant such a franchise to an American company, composed of Mr. Cyrus W. Field and others, has been pending in Congress for nearly a year, but, unfortunately, the enterprise resolved itself into a gigantic "job," involving a vast land grant, and a subsidy that would pay the entire expense of laying and operating the line in ten years: and Congress has very properly refused to sanction any such scheme of public plunder. It cannot be long, however, before the importance of such a line will be appreciated by our capitalists, and the work of laying it undertaken without either land grants or Government subsidies. Our trade with China and Japan is still in its infancy, but its promise of future development is encouraging, and a Pacific cable, uniting the British line along the China shore with the American system of land lines, and, through the latter, with several Atlantic cables, could not fail to command a large and profitable business.—*Iron Age.*

NEW BOOKS.

PAPERS ON THE THEORY AND PRACTICE OF COAL MINING. By GEORGE FOWLER, Mining Engineer, Basford, Notts. London: W. M. Hutchings, 5 Bouverie street. For sale by Van Nostrand.

We have in the small volume before us a very clear and able statement of the advantages attendant upon the "long-wall" system of mining, a system which we agree with Mr. Fowler in considering to be one worthy of being adopted far more extensively than it now is. In the opening chapter our author justly observes, that "it is very much the fashion, in the discussion of mining questions, to dilate on the diversity of circumstances, rather than the uniformity of conditions, affecting the working of coal, and he subsequently goes on to show that the different methods of mining adopted in different districts have not really arisen from any inherent peculiarities in those districts; but rather that the diversity in the systems has been caused by the want of ready means of communication, which in early times isolated, as it were, the miners of each of our chief coal fields. In fact, there are to be found in each of these coal fields workings differing from each other in character quite as widely as those of different districts. Again Mr. Fowler points out that if the methods of mining followed had been determined originally by peculiarities in the thickness of the coal and nature of the roof and floor, then it would be reasonable to suppose that in all districts seams worked under like conditions would have been worked in the same way; but this we need hardly say is not the case, and, therefore, there is strong ground for believing that the various systems followed originated, as Mr. Fowler supposes, from there being but little interchange of ideas between the different districts.

This point being allowed, it follows that there is a strong probability not only that one of the systems in use is preferable to all others where it is actually adopted, but also that it is preferable to others generally. This Mr. Fowler considers to be the case with the "long-wall" system, and he advances strong and clearly-stated arguments in support of his conclusion. The first chapter of his book is devoted to a general statement of the forces which operate upon a coal seam, and this portion of the subject is continued in the second chapter, which treats of the loads brought upon pillars in mines of different depths, and explains the manner in which the settlement of the roofs of workings takes place under different conditions.

In his third, fourth, fifth, and sixth chapters, respectively, Mr. Fowler describes the method of working adopted in the North of England, that generally followed in South Wales, the "leading and following up benkwork," principally used in Yorkshire, and the "long-wall" system. The three first-mentioned systems are each illustrated by a plan showing a colliery from which 100 acres of coal are supposed to have been worked, and which is capable of further extension; while the "long-wall" system is illustrated by two plans, each showing a similar colliery, the working in the one case being arranged on a true "long-wall" system, and in the other case on a kind of combination of a "board and pillar" and "long-wall" mine. The various arrangements shown in the plans are described briefly, and their peculiarities and the principles on which they are founded pointed out.

The descriptions of the various systems and their peculiarities occupy about half the book before us, and the remainder of the work is devoted to a comparison of these systems—a comparison which is carried out very fairly, and without any unjust prejudice in favor of the long-wall system. Mr. Fowler states that the elements of the cost of getting coal more or less common to all systems, are: hewing, loading, tramming, and onsetting, strait work, repairs of roads and windings, and interest on capital and plant. Besides these items there is, in the case of long-wall mines, the cost of making goaf roads, the principle of long-wall working being "to work the coal all out in long faces, and to bring the coals through roads packed through the goaf." In the first place our author points out that in all varieties of pillar working the area of pillar left for the support of the first working must increase with an increase of the depth of the mine, and that, therefore, the deeper the mine is, the greater will be the area under operation for a given extraction of coal. As regards the cost of hewing, Mr. Fowler considers that the long-wall method offers undoubted advantages, as where this system is adopted a less amount of side cutting is required to liberate a given quantity of coal than is necessary under other circumstances. The long-wall system also offers the greatest facilities for the employment of coal-cutting machinery, and we are inclined to believe that this latter fact will of itself have ultimately no small effect in promoting the adoption of the long-wall system.

On the cost of loading coal, the system of working adopted has little influence; but with the cost of tramming the case is different. The cost of tramming is made up of "putting" and engine haulage, and referring to the various plans of collieries already mentioned, Mr. Fowler shows that the mean length of "putting" distance will vary from 16 chains in the case of the North of England

system to 7 chains in the long-wall system, the relative cost varying also in the same proportion. The cost of engine haulage, unlike that of "putting," does not exactly vary as the distance through which the tubs are hauled, and Mr. Fowler makes reference to the valuable report of the tail-rope committee of the North of England Mining Institution for detailed information on the subject. The general deduction is, that the haulage costs in well-arranged long wall mines can be brought down to from one-half to two-thirds of those attendant upon other modes of working, while, when the cost of rails required is taken into consideration, there is an equally favorable balance in favor of the long-wall system. Mr. Fowler next compares the reduction of expenses due to the diminution of strait work with the cost of maintaining goaf roads attendant upon the long-wall system, the result being favorable to the latter, while the chapter on cost concludes with some pertinent remarks on the value of the products obtained by the different systems.

The eighth chapter is devoted to a consideration of the question as to how the fire damp given off by the coal can be best dealt with. Mr. Fowler advances good evidence that gas exists in coal in a highly compressed state, and he shows that a cut made across the cleavage planes of a seam drains the gas from the coal far more rapidly than a cut made parallel to those planes. We shall not attempt to epitomize here the various arguments which Mr. Fowler adduces to show that a system like the long-wall, in which the coal is mainly removed in slices parallel to the cleavage planes, is that which affords the greatest chance of security against explosion; but we shall merely remark that they are well founded and worthy of careful attention. As our author shows, the long-wall system affords great facilities for ventilation, and the gas being given off from the coal more gradually than in other methods of working, there is more chance of its being diluted and carried away without doing harm. The effective ventilation of the goaves is also another matter of which Mr. Fowler treats, and he gives much useful information concerning the quantities of doors, stoppings, and brattices, required for ventilating workings and goaves in mines laid out on different systems. Altogether, as we stated in commencing this notice, Mr. Fowler has made out a very strong case for the long-wall system of working, and he has produced an interesting book, which contains much useful information, and which we can strongly recommend to the perusal of all interested in colliery workings.—*Engineering.*

PERPETUUM MOBILE: OR, THE HISTORY OF THE SEARCH FOR SELF-MOTIVE POWER FROM THE THIRTEENTH TO THE NINETEENTH CENTURY. Second Series. By H. DIRCKS, C. E. LL. D., etc E. & F. N. SPON, Charing Cross. For sale by Van Nostrand.

In all ages of mankind there has been a tendency in the minds of practical and non-practical men to produce a machine or apparatus which shall by its own power keep itself moving for an indefinite period after it has been once started. Vast amounts of money have been spent upon the schemes by both rich and poor, for all classes have been led more or less into the belief that perpetual motion can be obtained in some way or other. In reading a work just published by Messrs. Spon, of Charing Cross, we are somewhat moved in wonder as to the large number of individuals who have tried the subject, and who have not only had models made to test their ideas, but have afterwards gone to the expense of patenting them to prevent other persons robbing them of the so-called inventions. The work has been compiled from pamphlets, patent specifications, and other documents, by Mr. H. Dircks, C. E. It is a complete repertory of what has been done on the subject, and should be read by all persons having a mechanical turn of mind, as it exposes the follies of quasi-mechanical men. We have selected the few concluding words of the author, the reading of which will prove the intrinsic value of the book to men of common sense and sound judgment.

"A more self-willed, self-satisfied, or self-deluded class of the community, making at the same time pretensions to superior knowledge, it would be impossible to imagine. They hope against hope, scorning all opposition with ridiculous vehemence, although centuries have not advanced them one step in the way of progress; and while their assumed novelties only prove their discomfiture by a retrograde process.

"Among them is a colonial bishop, a professor of philosophy, and another of languages, two barons, a knight of the most noble and ancient Order of the Temple, four military men, a doctor of medicine, a barrister, several gentlemen, two civil engineers, several mechanical engineers, a brass manufacturer, miller, millwright, smith, saddler, bobbin manufacturer, surveyor, and a geologist, besides others whose professions are not named.

"Among these one might expect to find a sufficient amount of education to have saved them from such an exhibition of misapplied energy as we have here. We can make every allowance for errors arising from the limited means of information possessed by the general public, even until late in the eighteenth century; and can view with curious eye the models and drawings of early artisans. But no apology can be offered for the abortive, ridiculous projects which are a discredit to the present age, enlightened as it is in all mechanical constructions; and the time has arrived when the infancy of mechanical scheming in impossibilities should be laid aside, or left as amusements for youthful amateurs. There is something lamentable, degrading, and almost insane in pursuing the visionary schemes of past ages with dogged determination, in paths of learning which have been investigated by superior minds, and with which such adventurous persons are totally unacquainted. The history of perpetual motion is a history of the foolhardiness of either half-learned or otherwise totally ignorant persons. In the infancy of sciences, whether medicine, chemistry, agriculture, mechanics, or others, there were, of course, some errors which received a certain amount of favor and even encouragement; but the crudities of every science are fast disappearing; alchemy is no more countenanced than is the search for a perpetual motion; and whatever hitherto may have sufficed to give an impulse to the latter has long since subsided, and, therefore, the benighted mechanic must work in unenvied seclusion; for there is no longer any expectation of applying such mechanism to the determining of the longitude, or of obtaining for its discoverer any Government reward.

"Were we to admit for argument's sake that some delicately arranged instrument might possi-

bly be contrived to show a tremulous action, its accomplishment would not be of the least practical value, or reward the toil and anxiety of its inventor. But, although inventors have sought a power exceeding the steam engine in some cases, while others have satisfied themselves with more lowly designs based on capillary attraction, neither the one nor the other has attained the faintest shadow of success. From the infant machines projected in the thirteenth century to the last hydraulic, pneumatic, weighted, and lever-worked pretensions patented as motions, no motion whatever has resulted from the one or the other to the present day. Not a solitary discovery is on record, not one absolutely ingenious scheme projected, or one simple self-motive model accomplished. Under such circumstances what shall we say of the modern mechanic who shall hereafter presume to add his dreary dreams to the lifeless lumber of the last seven centuries? No language can be too severe in denouncing the continuance of research in this insane undertaking; nor any criticism too sarcastic in exposing the foolish results pompously published by a class of blind, deaf, and doggedly stupid projectors, who, bringing obloquy on themselves, are a discredit both to their country and to the present enlightened age. Nothing can excuse the fostering of such crazed conceits as the present history records, curious in themselves as regards olden times, but ridiculous in a modern garb; they are, therefore, presented here as a warning to simple-minded experimenters and novices in mechanical science, in the hope thereby effectually to break the neck of this monster mechanical delusion."—*Mechanics' Magazine.*

THE KANSAS CITY BRIDGE, with an account of the regimen of the Missouri River, and a description of methods used for founding in that river. By O. CHANUTE, Chief Enginer, and GEO. MORISON, Assistant Engineer. New York: D. Van Nostrand, 1870.

This fine quarto is a rare addition to the literature of practical engineering. Such books from American engineers are scarce. The skilled members of the profession too often feel that they have discharged their whole duty, in successfully constructing the works under their charge; the lessons drawn from their experience are barely mentioned to a few professional friends, or, in rare cases, become the subject of a paper to be stored away in the archives of some society. The work of collating and arranging the records of such experiences is presumed to belong to another profession, if, indeed, there is a presumption that it is anybody's business. But the sum of such practical experiences constitutes engineering science. It is only he who builds, that knows how far the intricate formulas of physical science give results that accord with the exigences of the field, and it is such knowledge that is of especial value to the rising members of the profession.

The authors of the present work have realized the important relation they sustained to the confraternity of engineers, and have detailed with a rare felicity of method the practical devices by which they as engineers overcame great difficulties

The story is completely told; from the discussion of the physical character of the section which belonged to the reconnoissance, to the estimates and tests of deflection under change of temperature, or addition of a load—nothing relating to practical experience, whether mishap or success, is witheld.

The articles "Kansas City Bridge," and "Pier No. 4," in recent numbers of this Magazine, have, we are sure, sufficiently attested the value of this work to scientific readers. The book is beautifully printed, and is enriched with five lithographic views and twelve plates.

A TREATISE ON THE PRINCIPLES AND PRACTICE OF LEVELLING, Showing its Application to Purposes of Railway Engineering and the Construction of Roads. By FRED. W. SIMMS, C. E. From the fifth London edition, revised and corrected; with the addition of "Law's Examples of Railway Curves." New York: D. Van Nostrand.

This book was originally designed for young engineers who were obliged to work out the theory of levelling without the aid of an instructor. It is probably more widely known than any other book of its class. The explanations of the theory of levelling are of the clearest possible kind, and the applications are such as to enable the student to acquire the requisite skill in adjusting and working the instrument without other aid.

Law's curves furnish an epitome of the practical processes of laying out curves according to the best methods now in use.

The American edition presents the advantage over the London edition of exhibiting the diagrams on the same page as the reference in the text.

RESEARCHES ON DIAMAGNETISM AND MAGNE-CRYSTALLIC ACTION, INCLUDING THE QUESTION OF DIAMAGNETIC POLARITY. By JOHN TYNDALL, LL.D., F.R.S., etc., Professor of Natural Philosophy in the Royal Institution of Great Britain. London: Longmans, Green & Co., 1870. For sale by Van Nostrand.

The work before us is a first instalment of the collected publication of the author's original memoirs on experimental physics, communicated by him to the "Philosophical Transactions" and the "Philosophical Magazine," during the last eighteen years. These researches were begun at Marburg at the close of 1849, and have been since continued at Berlin, and completed in England. In the introdution to this series of memoirs, the author relates the discovery of, and first researches on, diamagnetism, by the celebrated Faraday. The first 184 pages are devoted to eight memoirs by the author, and the remainder of the volume contains letters, essays, and reviews relating to magnetism and electricity; the work as it is gives to the reader a very complete and excellent account of all facts and theories relating to this portion of natural philosophy. It is copiously illustrated with plates and wood-cuts, and is, in every sense of the word, a most interesting as well as useful publication.

EXPLOSIONS OF STEAM BOILERS. How they are caused and how they may be prevented. By J. R. ROBINSON. Boston: Little, Brown & Co. For sale by Van Nostrand.

The author of this little volume is a practical engineer and has evidently been a close observer of the phenomena attendant upon steam-boiler explosions. He advances the theory that, under some conditions of interior boiler surface and of feed water, there is no contact of water with the heated surface, even at considerable depths below the water level; that there is a decided repellant

action between the water and the metal, even at temperatures and pressures which are quite common in working boilers. A variation in temperature in the boiler surface, or of pressure on the water, may enforce a contact of liquid metal at a critical moment, and cause such a violent vaporization of the water as to cause an explosion.

Mr. Robinson's conclusions seem to be fairly enough drawn from his experiments, and it is evidently a profitable field for further trials.

It is to be hoped that the limiting temperatures at which such action as above described can occur, may be determined for all conditions of the water as to substances in solution, and for the different states of boiler surface.

The book is printed in a much neater style than is common with works on kindred subjects.

EARTH AND SEA. From the French of LOUIS FIGUIER. Translated, edited, and enlarged by W. H. DAVENPORT ADAMS. Illustrated with 250 engravings by distinguished artists. For sale by Van Nostrand.

This is simply a work on Physical Geography, beautifully printed and illustrated, and expanded by descriptions of remarkable localities, to the unprecedented dimensions of 700 pages, royal octavo.

It is well known that Figuier aims in his works at making science look attractive by keeping its technicalities out of view and bringing forward and illustrating the striking phenomena and features. Such books find their uses in attracting to the severer study of science young readers who would not otherwise be drawn from easier studies or diversions.

This new work is more to our liking than either of the preceding ones by this author. The peculiarities above referred to are manifested in the large space afforded to avalanches, earthquakes, volcanoes, and like phenomena, and the absence of classifications of winds, currents, climates, etc.

It is a beautiful book for the private library, and will prove deeply interesting to the general scientific reader.

THE ELEMENTS OF MECHANISM. By T. M. GOODEVE, M.A. London: Longmans. For sale by Van Nostrand.

This book, designed especially for students of applied mechanics, has been published previously as a separate and independent work, but has now been rewritten and enlarged, in order to fit it to form one of the series of Elementary Text-books on Mechanical and Physical Science in course of publication by Messrs. Longmans. It contains descriptions with illustrations of all the more important mechanical movements, with chapters on "the Teeth of Wheels;" on "the Use of Wheels in Trains," including articles on the "Screw-cutting Lathe, Cranes, and the Connection of Axes;" on "Agregate Motion," and articles on numerous miscellaneous contrivances. The volume will prove a handy *vade-mecum* to all students of mechanics as applied to the industries of the world. It is well printed, and the cuts are, as a rule, illustrations of the actual movements to be observed in existing machines.

A PRACTICAL TREATISE ON SOLUBLE OR WATER GLASS, Silicates of Soda and Potash for Silicifying Stones, Mortar, Concrete, and Hydraulic Lime, rendering Wood and Timber Fire and Dry-Rot Proof. By Dr. LEWIS FEUCHTWANGER. New York: L. & J. W. Feuchtwanger. For sale by Van Nostrand.

The various uses of soluble glass were fully set forth in the last number of our magazine. The book before us presents a compilation of all the author could find in journals and Patent Office reports.

A large space is devoted to limes and cements, and proposed applications of soluble glass in connection with them.

The work bears marks of haste in its preparation, but from the large fund of information on mineralogical and chemical subjects, promised by the author, the book cannot fail to be of value.

LIGHT-HOUSES AND LIGHT-SHIPS. A Descriptive and Historical Account of their Mode of Construction and Organization. By W. H. DAVENPORT ADAMS. London: T. Nelson & Sons. For sale by Van Nostrand.

The topics discussed in this little book are under the following heads:

1. Ancient history of light-houses.
2. The science of light-houses.
3. Light-houses of Great Britain.
4. Light-houses of France.
5. The auxiliaries of light-houses.
6. Life in the light-house.

The illustrations are excellent and numerous, and the work is a good addition to the list of popular scientific treatises which have appeared within the last two years.

THE NAVAL DRY DOCKS OF THE UNITED STATES. By CHAS. B. STUART. Illustrated with twenty-four fine engravings on steel. Fourth edition. 4to, 220 pages. New York: D. Van Nostrand.

The value of this work is attested by engineering readers whose libraries are enriched by the three previous editions.

THE MANUAL OF THE HYDROMETER, with Chapters on Oxidation and Depositions in Marine Boilers. By LIONEL SWIFT, R.N. Portsmouth, Eng.: Griffen & Co. For sale by Van Nostrand.

CONTENTS: Hydrometers and their use, with practical examples; Specific gravity of sea water; Amount and character of saline ingredients; On the deposits in marine boilers; Causes and prevention of boiler priming; Oxidation in boilers—cause and prevention; Practical summary of the management of boilers and superheaters.

MISCELLANEOUS.

FAURE'S BATTERY.—Faure's element is a modification of that known as Bunsen's, the poles consisting of carbon in strong nitric acid and amalgamated zinc in dilute sulphuric acid. In Bunsen's ordinary form of carbon element the carbon pole is immersed in a vessel holding a considerable quantity of nitric acid, which, as it becomes de-oxidized by the electrolytic action of the current, liberates nitrous acid gas, which rises into the air, rendering it unwholesome to breathe, and destructive to most metallic apparatus in its neighborhood. The purpose of Faure's battery is to obviate these drawbacks. This is effected by confining the nitric acid inside the carbon pole and allowing only sufficient acid to percolate through

it, in order to keep up the necessary electrolytic action of the element. The carbon pole is made in the form of an ordinary bottle, and is provided with a carbon or platinum stopper, to which the binding screw of the pole is attached. This bottle, which fulfils at once the functions of both pole and porous diaphragm, is placed concentrically in the interior of a cylinder of amalgamated zinc. And the whole is contained in an earthenware jar. When set up for action the bottle is nearly filled with the nitric acid, and the space containing the zinc, between the bottle and the outer jar, to the required height with the dilute sulphuric acid. The slight liberation of gas within the bottle causes a sufficient pressure to be exerted upon the nitric acid to force it gradually through the carbon. In this way the exterior of the carbon pole remains immersed in a very thin layer of nitric acid immediately opposite to the zinc, which is in course of dissolution in the dilute sulphuric acid In point of constancy this element is superior to either Bunsen's or Grove's, because the body of nitric acid remaining protected within the bottle does not become weakened, as is the case with those forms of elements in which the two fluids are exposed in larger quantities and separated by porous diaphragms. It acts also entirely without any disengagement of gas into the air, so that it may be used in any room without disagreeable consequences. A variety of forms might no doubt be given to these elements which would enable them to fulfil the desired object. Those which I have placed upon the table were designed and manufactured by Messrs. Elliott Brothers, and are found to be convenient for experimental purposes as well as for use in telegraph offices.—*The Artizan.*

Steel Spring Motor for Street Cars.—The following is a description of a new application of steel spring which has been patented recently by P. E. McDonnell, of Chicago :—"In the device, coil springs about twenty inches wide, three-sixteenths of an inch thick, and of suitable length, are placed under the platforms, and by means of suitable gearing their power is concentrated on a shaft, from which it is taken and applied to rotating the journals, the springs uncoiling slowly, but giving a quick rotary motion to the car wheels. One or both springs may be used, as the case may require, and the gearing may be reserved to move the car in either direction, while a governor regulates the speed. The car is under the perfect control of the engineer, and it can be stopped and started much quicker than when operated by horses ; inasmuch as the power required to propel the car is used to stop it, and the inertia acquired in running is used to stop it, very ingenious machinery being used to accomplish this result. It is expected that an engine will be used at the end of the route to wind up the springs, an operation requiring about two minutes and a half time, and when wound, they are supposed to propel a car five miles, carrying sixty passengers. One great peculiarity in the mechanism consists in the fact that the movement of the car down an incline is made to wind up a spring, which is used to propel the car up grade."

New Gold Washing Apparatus.—An ingenious and very complete apparatus for working auriferous river beds has been invented by Mr. A. F. Errington, of Sebastapol, Ballarat. The first cost of the apparatus complete is between £6,000 and £7,000, the total working expenses are calculated at £160 per week, and wash-dirt yielding only 5 dwts. per ton upon the average will realize no less than $2,000 sterling per week. The boat is to be propelled by a Penn's oscillating cylinder-engine, with undershot water-wheels to increase (?) the motive-power, the engine also working the gold-washing machinery. A vertical rod passing through an aperture in the hold serves for the buckets to descend upon to the river bed. The wash-dirt raised by the bucket to the upper deck is discharged into a hopper, wherein water pumped up through a hollow mast is thrown upon it. After being washed through perforated cylinders the valuable portion of the dirt is received in two cradles, from which the auriferous deposit is lifted by hand into revolving basins in which the heavier gold is separated from the debris.

Utilizing Coal Waste.—Perhaps one of the most important, inasmuch as it has been demonstrated to be practical, inventions of the day, in view of the high prices of fuel, is that referred to under the above caption. Some time since, a company was formed in this city, with a view to utilizing the refuse of coal mines, the accretions of which have not only been enormous, but of serious inconvenience to the operator, and hitherto valueless. The enterprise has proved a complete success, buildings and machinery have been erected at Mauch Chunk, and the fuel, as prepared from the coal dust, is said to be superior to the natural coal, burning without cinder or impurity of any kind. Unfortunately for the good of the general public, the Secretary of the Navy, after testing the fuel, has entered into a contract for all the present works are capable of turning out. The fuel, as supplied the government, is in cubes of five inches. From the regularity of shape, great advantage can be had in stowage, while the absence of cinder and, comparatively, of ashes, renders it peculiarly desirable. The price is said to be lower considerably than that of coal in its present form. The supply of the refuse is inexhaustible, and this improvement gives us another advantage over the impracticable miners, who may strike at will if we can but utilize the dust which we have above ground by millions of tons. As a process has been lately ventilated by which coal has been ground to a fine dust, and carried by blowers into the furnace with sufficient air to produce immediate combustion, and with the most eminent success, we suggest the use of the dust already on hand for similar treatment, not doubting equal results will be obtained. Any process or invention which cheapens the necessaries of life to the consumer is of prime value, and as fuel may be looked upon as the *sine qua non* of industry, as of comfort, the inventions alluded to deserve more than casual notice.—*Iron Age.*

When 2 or 4 per cent. of finely pulverized althea root (marsh mallow) is mixed with plaster of Paris, it retards the hardening, which begins only after half an hour's time. When dry, it may be filed, cut, or turned, and thus become of use in making domino-stones, dies, brooches, snuff-boxes, etc. Eight per cent. retards the hardening for a long time, but increasing the

tenacity of the mass. The latter may be rolled out on window-glass into thin sheets, which never crack in drying; may be easily detached from the glass, and take on a polish readily by rubbing them. This material, if incorporated with mineral or other paints, and properly kneaded, gives very fine imitations of marble, and can be colored when dry, and can be made waterproof by polishing and varnishing. The chemist and chemical manufacturers will find it an excellent luting for vessels of every kind.

Probably the best polishing powder for metals of medium hardness and for glass would be that used by Lord Rosse for polishing the speculum of his large telescope. He thus describes his method of preparing it: "I prepare the peroxide of iron by precipitation with water of ammonia, from a pure dilute solution of sulphate of iron. The precipitate is washed, pressed in a screw-press till nearly dry, and exposed to a heat, which, in the dark, appears a dull, low red. The only points of importance are that the sulphate of iron should be pure and the water of ammonia should be decidedly in excess, and that the heat should not exceed what I have described. The color will be a bright crimson, inclining to yellow. I have tried both potash and soda, pure, instead of water of ammonia, but after washing with some degree of care, the trace of the alkali still remained, and peroxide was of an ochrey color, and did not polish properly."

According to Dr. R. Fresenius, the weighed quantity of iron to be tested for carbon is placed on a small porcelain boat, and introduced into a hard glass combustion tube, placed in a combustion furnace, and, when red hot, a current of dry chlorine gas (dried by making it pass over pieces of pumice-stone moistened with strong sulphuric acid), is passed over; the current of gas and application of a low red heat is continued until all the iron is volatilized as chloride. The carbon left in the small boat is, after the apparatus has cooled, placed in a porcelain tube and burned. After being heated to redness in a current of oxygen, the products of the composition are taken up by Liebig's potash bulbs. Great care is required that the chlorine be thoroughly dry, since, otherwise, hydrocarbon may be formed and some carbon lost.

Prof. J. B. Schnetzler, in his observations on the spontaneous motion of the protoplasm in the cells of the leaves of the common water-weed, *Anacharis alsinastrum*, recently published, expresses the opinion that the principal cause which provokes the motion is the chemical action of oxygen, which passes through the wall of the cell, and of which a portion is probably transformed into ozone under the influence of light, as occurs also in the globules. The currents thus produced are influenced by the highest refracted rays of light, and also, probably, by electricity formed under the influence of water between the surface of the leaf and the contents of the cells.

In Belgium furnace slag is now utilized by allowing it to run off into moulds along the sides of the furnace, in which it assumes the form of rectangular blocks of any size. When cold, the mass forms a compact, homogeneous slag, very much resembling porphyry, and equal, for building and engineering purposes, to the best natural stone that can be procured from the quarry.

Commerce of the World.—France exports wines, brandies, silks, fancy articles, furniture, jewelry, clocks, watches, paper, perfumery, and fancy goods generally.

Italy exports corn, oil, flax, wines, essences, dye stuffs, drugs, fine marble, soaps, paintings, engravings, mosaics and salt.

Prussia exports linens, woollens, zinc, articles of iron, copper and brass, indigo, wax, hams, musical instruments, tobacco, wine and porcelain.

Germany exports wool, woollen goods, linens, rags, corn, timber, iron, lead, tin, flax, hemp, wine, wax, tallow, and cattle.

Austria exports minerals, raw and manufactured silk, thread, glass, wax, tar, nutgall, wine, honey, and mathematical instruments.

England exports cotton, woollens, glass, hardware, earthenware, cutlery, iron, steel, metallic wares, salt, coal, watches, tin, silks and linens.

Russia exports tallow, flax, hemp, flour, iron, copper, linseed, lard, hides, wax, ducks, cordage, bristle, furs, potash and tar.

Spain exports wine, brandy, oil, fresh and dried fruits, quicksilver, sulphur, cork, saffron, anchovies, silks and woollens.

China exports tea, rhubarb, musk, ginger, borax, zinc, silks, cassia, filigree works, ivory ware, lacquered ware and morocco.

Hindostan exports gold and silver, cochineal, indigo, sarsaparilla, vanilla, jalap, fustic, campeachy wood, pimento, drugs and dye stuffs.

Brazil exports coffee, indigo, sugar, rice, hides, dried meats, tallow, gold, diamonds and other precious stones, gums, mahogany and india rubber.

West Indies export sugar, sugar molasses, rum, tobacco, cigars, mahogany, dye woods, coffee, pimento, fresh fruit and preserves, wax, ginger and other spices.

Switzerland exports cattle, cheese, butter, tallow, dried fruits, linen, silks, velvets, lace, jewelry, paper, and gunpowder.

East India exports cloves, nutmegs, mace, pepper, rice, indigo, gold dust, camphor, benzine, sulphur, ivory, rattans, sandal wood, zinc, and nuts.

United States exports, principally, agricultural produce, cotton, tobacco, flour, provisions of all kinds, lumber, turpentine, wearing apparel.—*Iron Age.*

Drawing an analogy from the motion of a cannon ball, we shall find that, supposing the earth to be arrested suddenly while travelling through space at the rate of 19 miles per second, as much heat would be developed as would be given off from the combustion of a volume of oil 14 times the size of the earth.

In front of Krupp's establishment shells of the largest calibre are to be seen lying. They are in the form of a pointed cylinder, and are 3 ft. long and 14 in. in diameter. When filled with their charges (76 lbs. of powder) they weigh 739 lbs. A hundred of these explosive projectiles have been ordered to be forwarded to Paris as speedily as possible.—*The Engineer.*